Evidence-based practice has become an increasing important concept to the athletic training profession. The fifth edition of the National Athletic Trainers’ Association Athletic Training Education Competencies requires students to be introduced to low level laser therapy (LLLT; Figure 1). The effectiveness of this modality has not yet been fully established and most athletic training faculty members did not learn about it during their professional education. One of the most difficult aspects of understanding LLLT is the large number of treatment parameters that can be manipulated. This report reviews the available research evidence pertaining to LLLT wavelength, average power, average energy, total energy density, number of treatment sites, and the number of treatment sessions. Wavelength and total dosage appear to have the greatest impact on the treatment effect.2-3

Wavelengths of 600–1000 nm are ideal for therapeutic effects. Wavelengths shorter than 600 nm tend to scatter, rather than to penetrate deeply into the body tissues. Longer wavelengths are absorbed in the deeper tissues.4 The energy density of LLLT (i.e., dosage) is determined by power density (mW), time(s), and beam surface area (cm²), which is represented by Joules/cm².4 Total energy (J) and energy density (J/cm²) are different quantities. Energy is equal to Power (W) × Time (s). The energy delivered by manipulating the number of Joules is not the same as that derived from manipulating the J/cm², which is the power density.4 Published treatment patterns vary. The World Association of Laser Therapy (WALT) published a set of treatment parameter recommendations in 2010.5 Because the WALT recommendations only address the wavelength, dosage, and treatment size, other treatment parameters reported in the research literature can lead to confusion. The available literature suggests that LLLT has a positive effect on cellular

Key Points
- Low level laser therapy appears to promote tissue healing through increased ATP synthesis.
- Research evidence supports low level laser therapy for treatment of dermatological conditions.
- Optimal parameters for treatment musculoskeletal injuries have not been clearly established.
activity, which could promote tissue healing.\textsuperscript{6-10} The varying wavelength and total energy treatment parameters used in studies of dermatological injuries and cellular activity have been reported to be beneficial, but studies of musculoskeletal injuries have produced inconsistent results.

**Cellular Mechanisms**

The first reported use of LLLT in 1971 was administered to reduce the healing time of animal wounds.\textsuperscript{11} The mechanism by which the treatment decreased wound healing time was not understood at the time, but recent evidence suggests that LLLT has effects at cellular and molecular levels.\textsuperscript{12-15} Photons are absorbed by the molecules, which increases the energy level through excitation of electrons. Energy derived from LLLT is absorbed by cytochrome c oxidase (CCO) within the mitochondria.\textsuperscript{13} Increased CCO activity promotes greater synthesis of adenosine triphosphate (ATP), which supports increased production of cell proteins.\textsuperscript{9,13,15-19} The healing process is believed to be facilitated by accelerated production of collagen fibers by fibroblasts during the repair and remodeling phases. Multiple studies have reported an increased number of fibroblasts\textsuperscript{6,8,20} and increased collagen production following exposure to LLLT.\textsuperscript{19,21}

**Treatment of Dermatological Conditions**

The use of LLLT for the treatment of dermatological conditions is supported by numerous studies.\textsuperscript{11,14,17-18,20,22-23} With the exception of one study,\textsuperscript{24} LLLT has consistently demonstrated therapeutic benefit for wounds, burns, and scars, including faster healing time and decreased hypertrophic scar tissue.\textsuperscript{11,14,17-18,20,22-23} The collective findings of a number of studies suggest that LLLT enhances collagen synthesis.\textsuperscript{6,8,9,14,17-18,20,22-23} Hopkins et al.\textsuperscript{23} suggested a possible systemic effect on healing, because both of two wounds created 5 cm apart healed faster when only one of them was treated with LLLT. Lack of consistency in the treatment parameters utilized among the studies presents a challenge to clinicians who seek to achieve the desired treatment effects.

Studies of the effects of LLLT on dermatological conditions have involved wavelengths that varied from 630 nm to 904 nm, all of which provided therapeutic benefit.\textsuperscript{6,8,9,14,17-18,20,22-23} The only study that specifically addressed different wavelengths demonstrated that 670, 692, 780, and 786 nm stimulated cell growth, but the 780 nm wavelength (infrared) was significantly more effective than the 670 nm wavelength (visible).\textsuperscript{6} Average power outputs have varied from 8.8 to 25 mW, total dosages from 2 to 8 J/cm\textsuperscript{2}, frequency of treatment from 12 to 24 hours, and duration of treatment from 1 to 2 weeks.\textsuperscript{14,22-23} Treated tissues have included sites on the arms and feet, and excised skin cells. Manuskiatti and Fitzpatrick\textsuperscript{24} administered LLLT 6 times at 4 week intervals, which failed to demonstrate a beneficial effect. This treatment cycle was very different from all of the other studies that were reviewed. Overall, the research evidence supports the use of LLLT for treatment of dermatological conditions. A possible explanation is that there is very little tissue for the laser to penetrate in order to reach the skin cells.

**Treatment of Musculoskeletal Conditions**

Control of inflammation, pain reduction, and improvement of joint range of motion are primary treatment goals for musculoskeletal injury management. The administration of LLLT may contribute to realization of each of these goals, as well as facilitation of tissue regeneration.\textsuperscript{3,13,15,24-26} Research evidence supports reduction of PGE\textsubscript{2} level in human Achilles tendon,\textsuperscript{27} reduced carrageenan-induced edema in rats,\textsuperscript{28} and increased collagen production in repaired rat tendon.\textsuperscript{19} A systematic review indicated that 18 out of 19 relevant studies demonstrated that LLLT can control the inflammatory process in injured tissue.\textsuperscript{29} Anti-inflammatory effects appear to occur within a small therapeutic window and are dose-dependent.\textsuperscript{30} Increased mitochondrial density and muscle fiber cross-sectional area have been documented,\textsuperscript{21} as well as cell growth.\textsuperscript{8} The Arndt-Schulz Law suggests that low dosage can have a beneficial stimulatory effect, but negative responses can result from high dosage.\textsuperscript{4,8,31} However, a dosage that does not meet a minimum energy threshold will not elicit a positive biological response.\textsuperscript{4} The minimum energy density threshold may be as low as 0.4 J/cm\textsuperscript{2} and a power density of 5 mW/cm\textsuperscript{2}.\textsuperscript{36} Biological changes result from the absorption of light energy, which is dependent on both the wavelength and the qualities of the tissue.\textsuperscript{31-52} Bjordal et al.\textsuperscript{29} did not find evidence that cell changes were dependent on wavelength, but neither did they rule out the possibility that some wavelengths might be more effective than others. Absorption of energy by tissues that are close to the source of light energy reduces the amount of energy...
that can be transmitted to deeper tissues and adjacent tissues.\textsuperscript{33} Furthermore, different types of tissue may exhibit variable responses to specific wavelengths or dosage levels, and different treatment goals (i.e., control of inflammation versus tissue synthesis) might require different treatment parameters.\textsuperscript{29}

Multiple systematic reviews have suggested that LLLT appears to have beneficial therapeutic effects on musculoskeletal injuries, but there are research reports that present conflicting findings (Figure 2).\textsuperscript{34-37} Lack of consistency among studies of LLLT effectiveness for management of musculoskeletal injuries is likely due to methodological flaws, such as insufficient sample size, inadequate inclusion criteria, lack of blinding, inappropriate treatment parameters, and lack of appreciation of a dose-response influence on treatment outcomes. Comparisons of findings among studies of LLLT is greatly complicated by use of different wavelengths and dosages.\textsuperscript{25,26, 38-51} Different wavelengths (e.g., 904 nm, 780–860 nm, and 890 nm) have produced conflicting results. Most studies have used either energy (J) or energy density (J/cm\textsuperscript{2}) as a treatment parameter, but they represent the combination of power and time in ways that differ from one another.\textsuperscript{29,52} Power intensity, irradiation time, and beam surface area contribute to the energy density dosage delivered to the tissues by LLLT.\textsuperscript{33} Research evidence clearly supports the potential benefit of LLLT for treatment of musculoskeletal injuries, but the inability to synthesize the collective findings of numerous heterogeneous studies precludes specification of optimal treatment parameters.\textsuperscript{3,11-12,25,41,43-44,46,48,51}

**Conclusions**

A reduction of skin wound healing time through the use of LLLT is clearly supported by research evidence.\textsuperscript{13,15,22,26} The available research literature suggests that LLLT may help to control inflammation and promote collagen synthesis, both of which could reduce healing time following a musculoskeletal injury.\textsuperscript{3,11-12,41,43,46,48,51} The precise physiologic mechanisms of therapeutic benefits derived from LLLT are unclear and optimal treatment parameters are difficult to determine from the current literature. More research is clearly needed to guide clinical utilization of this therapeutic modality.

**References**


**Figure 2** LLLT used to treat an ankle injury.


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