Phototherapy Applications In Sports Medicine

Biophotostimulation of cells are helpful in accelerating healing in injured tissues.

By William J. Kneebone, CRNA, DC, CNC, DIHom, FIAMA, DIACT

In this issue, I want to introduce you to Doug Johnson who has written the first of two planned articles. This first article covers the use of therapeutic laser and phototherapy for treating painful sports injuries. In his second article, he will discuss the use of therapeutic laser and phototherapy in the industrial rehabilitation setting.

—Dr. Kneebone

By Douglas Johnson, ATC, CLS

Participation in high school sports helps promote a physically active lifestyle. Participation has grown from an estimated 4 million participants during the 1971-1972 school year to an estimated 7.2 million in 2005-2006.[1] Despite the documented health benefits of increased physical activity (e.g., weight management, improved self-esteem, increased strength, endurance, and flexibility[2]), those who participate in athletics are at risk for sports-related injuries[3,4] (see Figure 1).

Participation in any sporting activity carries an inherent risk associated with the nature of the sport and the physical demands placed on the players (see Table 1). High school athletes account for an estimated 2 million injuries, 500,000 doctor visits, and 30,000 hospitalizations annually.[5] While the health benefits of a physically active lifestyle that includes athletic participation are well known, the risks for sports-related injury and effective prevention strategies are less well established. Therefore, a comprehensive injury management program needs to be in place to not only to return an athlete to competition but to minimize the potential for re-injury.

Phototherapy, a therapeutic physical modality using photons (light energy) from the visible and infrared spectrum for tissue healing and pain reduction,[6] has been shown to address a variety of applications in the field of sports medicine and continues to grow in popularity.

In most instances, athletic injuries are acute in nature and the athlete can describe the exact nature and mechanism of injury. Response to sports injuries can involve soft and bony tissue and consist of acute and chronic inflammatory healing factors.

Acute soft-tissue healing consists of the acute, repair and regeneration, and remodeling phases. The acute phase lasts 3 to 4 days. During initial trauma, transitory vasoconstriction occurs, followed by vasodilatation and increased permeability. The second phase of soft tissue healing repair and regeneration extends from the inflammatory phase of 48 to 72 hours to approximately 5 weeks. It consists of resolution, development of granulation tissue and, finally, regeneration of lost tissue, depending on the extent of the injury. The development of more granulation tissue in the second phase has a greater possibility of producing excessive scar tissue.[7]

Inflammation that lasts for months, or even years, is termed chronic. It may occur as a result of acute micro trauma and overuse. Scar tissue and degeneration are associated with chronic inflammation.

Photobiostimulation

Photobiostimulation is the process where a chain of chemical reactions is triggered by exposure to light. After an injury occurs, damaged cells produce a combination of edema, inflammation, pain, and loss of function. An athlete's response to laser therapy depends upon their physiological status.[8] Injured cells and tissues emit enzymes that encourage the receipt of photons more

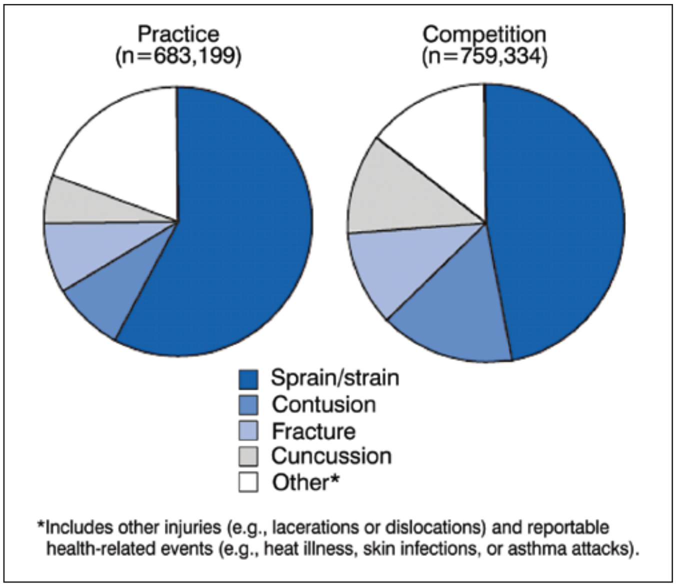

FIGURE 1. *Proportion of injuries in practice and competition, by diagnosis. high School Sports-Related Injury Surveillance Study, United States, 2005-2006 school year.*
http://www.cdc.gov/mmwR/preview/mmwrhtml/mm5538a1.htm Accessed 2/7/07

readily than healthy cells and tissues. Primary photoacceptors, which are activated by light, are thought to be flavins, cytochromes (pigments in the respiratory chain of cells), and porphyrins.[9,10] They are located in mitochondria and can convert light energy to electro-chemical energy. This mechanism provides a theoretical framework in which a very small amount of energy can cause very significant biological effects.

Before any reactions can occur, the emitted photons—the basic unit of light; a packet or quantum of light energy—must be absorbed by the target tissue (Law of Conservation). The absorption of light and its subsequent biological effects depend on the wavelength—regardless of the power output, the technical design of the apparatus, whether the laser is super-pulsed, or treatment technique used.

Based upon the vast body of research, applications of visible red (600 - 700 nm) and infrared (from 700 to 1000 nm) wavelengths produce therapeutic effects in the cell referred to as photobiostimulation. These two broad categories of wavelengths can be produced by a variety of devices.

Dr. Mary Dyson has classified phototherapy and its effects on the body into primary, secondary and tertiary effects. It is the unique synergy between the three responses that create the phototherapeutic effect:

Primary effects —are created by direct photoreception of photons with cytochromes resulting in increases in ATP production and changes in cell membrane permeability; this response is specific to phototherapy. Photoreception is generally followed by transduction of light into cellular energy, amplification of the signal and a photo-response—the last of which can be classified as either secondary or tertiary.

Secondary effects —occur in the same cell in which photons produced the primary effects; they are induced by these primary effects. Secondary effects include cell proliferation, protein synthesis, degranulation, growth factor secretion, myofibroblast contraction and neurotransmitter modification, —depending on the cell type and its sensitivity. They are less predictable than primary effects with the sensitivity of the cells dependent on internal and external environment factors.

Tertiary effects —are the indirect responses of distant cells to changes in other cells that have interacted directly with photons. They are the least predictable because they are dependent on both variable environmental factors and intercellular interactions. They are, however, the most clinically significant. Tertiary effects include all the systemic effects of phototherapy.

Sport-Specific Injury Rates

Sport	Rate: Practice	Rate: Competition	Rate: Overall
Boys' football	2.54	12.09	4.36
Boys' wrestling	2.04	3.93	2.50
Boys' soccer	1.58	4.22	2.43
Girls' soccer	1.10	5.21	2.36
Girls' basketball	1.37	3.60	2.01
Boys' basketball	1.46	2.98	1.89
Girls' volleyball	1.48	1.92	1.64
Boys' baseball	0.87	1.77	1.19
Girls' softball	0.79	1.78	1.13
Total	**1.69**	**4.63**	**2.44**

* Per 1,000 athlete exposures (i.e., practices or competitions).

TABLE 1. *Sport-specific injury rates* in practice, competition, and overall. High School Sports-Related Injury Surveillance Study, United States, 2005-2006 school year.*
http://www.cdc.gov/mmwR/preview/mmwrhtml/mm5538a1.htm Accessed 2/7/07

Contraindications for Laser Therapy

ABSOLUTE CONTRAINDICATIONS:
Pregnancy
Carcinoma
No treatment over the thyroid gland
No treatment over epiphysis of children
Immune suppressant drugs/Transplant patients
Photosensitive patients

CONSIDERATIONS:
Botox injection sites
Anti-inflammatory medications
Steroid Injections

OTHER CONSIDERATIONS:
Wounds — ensure wounds are completely cleaned from any topical applications and debrided prior to treatment
Anticoagulants
Tattoos
Chronic musculoskeletal localized inflammation

Adapted from North American Association for Laser Therapy (NAALT) standards. June, 2006; Toronto, Canada[21]

TABLE 2. *Contraindication for Laser Therapy.*

It is the summation of primary, secondary and tertiary events that produce phototherapeutic activity. Its effectiveness should be monitored non-invasively as the course of treatment progresses and the treatment parameters modified, if necessary.[11] This brings up a very important topic of target-specific treatment.

If the primary effect of phototherapy is the result of direct stimulation to the injured tissue, then the goal of any type of treatment should be to “hit the target” with light. This sounds simple enough; however, wavelength and energy density can impact the ability to reach certain targets, particularly those at certain depths.

All light emitting devices, even low powered ones, produce some heating through transduction when the photons are absorbed by the chromophores within the cell. These small temperature differences can affect cell membrane permeability and are fundamental to many of the secondary effects of phototherapy.[12]

So while some of the effect can be attributed to heating of the tissue, it should be noted that the primary effects of phototherapy are not dependent on the transfer or generation of heat in the tissue. Too much heat, as in the case of a surgical powered laser, can be precarious to human tissue; a laser beam of MOP about 200 mW, focused on an area of 1 cm2 (power density 200 W/cm2) for about 10 minutes is all that is needed to produce first degree burns.[13]

Though critics of phototherapy may continue to debate its overall effectiveness, the overwhelming scientific and clinical outcomes support the successful use of this new modality. Phototherapy has been shown to be effective in the management of some common athletic injuries: ankle sprains,[14] Achilles' tendonitis,[15] shoulder tendonitis,[16] medial and lateral epicondylitis,[17] cervical pain,[18] and wounds/abrasions.[19] It should no longer be a question of whether light has a biological effect on tissue but rather what are the optimal parameters for the successful uses of these light sources. Additional research—conforming to the standards that have been established by the World Association of Laser Therapy (WALT)[20]—is necessary to further validate the present findings.

Contraindications

In 2006, many of the leading phototherapy practitioners discussed the contraindications to phototherapy at the North American Association of Laser Therapy annual Congress in Toronto, Canada (see Table 2). In previous years, the list of contraindications was divided into only absolute and relative contraindications. This congress adapted a new set of guidelines that are divided into three classes: absolute, considerations, and other considerations.[21] In particular to sports medicine professionals was the addition of the treatment of children at the epiphysis of bones. While anti-inflammatory medication is commonly prescribed, the use of NSAIDs is well documented to decrease the effectiveness of photobiostimulation.[22] Therefore, light therapy is not indicated for patients who are on either oral or injectable anti-inflammatory medication therapies.

"When electing phototherapy treatments for acute injuries, care needs to be taken regarding the stage of healing of the injury. Some phototherapy devices may emit a great deal of heat with the light, and this is contraindicated in the acute phase of healing."

Muscle Spasm and Muscular Pain

The treatment of muscle spasm and muscular pain are two of the more common phototherapy applications. Excellent results can be achieved in a minimal amount of time when utilizing proper technique. This type of application requires the probe to be in contact with the skin, at the site of the spasm, and applied with a mild over-pressure. Based on the mode of power output, two different applications may be used.

Continuous wave (CW) lasers require specific energy dosage, measured in joules, to elicit a phototherapeutic response. Pontinen's Principle is designed to maximize treatment response in a single visit and to ensure that sufficient dosage has been provided. The technique is to palpate the spasm and have the patient rate their pain. The laser is used to administer 6-8 J/cm^2 directly to the spasm. Upon completion of the treatment, clinicians will reassess for pain response. If pain persists, two additional applications may be given to get a treatment response.

Unlike CW lasers, super pulsed (SP) lasers emit beams that are always pulsed to set frequencies (see Figure 2). This pulsing determines the treatment depth and, to some extent, the type of tissue response of the injured area. Generally, higher frequencies are use to stimulate tissue and for the relaxation of muscle spasm. Dosimetry for SP lasers is usually given in time units (sec-

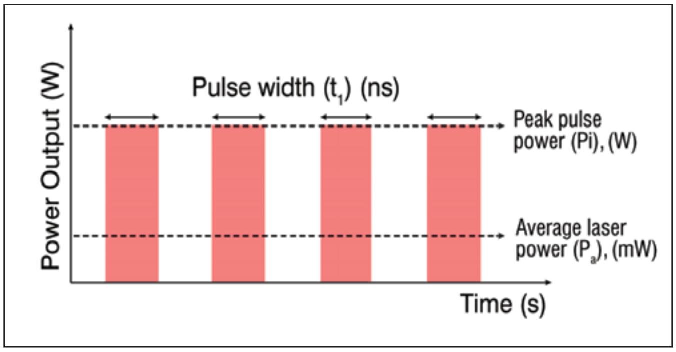

FIGURE 2. *Super-Pulsed Lasers are pulsed to a set frequency. (Copyright Medical Quant USA. Used with permission.)*

onds), rather than energy units (joules). After assessing the patient's pain and spasticity of the muscle, one would set a frequency between 700 and 2500 Hz with the SP laser and apply the dose for approximately 2-3 minutes with mild over-pressure. After re-palpating and re-assessing, continued pain or spasm can be treated up to two additional times to reduce pain and spasm.

In both types of applications, the use of single probe or optical light guides is recommended. The greater concentration of the energy (energy density) as well as the physical trigger point techniques can be used to further decrease the spasm. On average, athletes should experience immediate relief of minor spasms. Chronic spasm, or moderate to severe spasm, may require several applications before getting results.

Acute Injuries

When electing phototherapy treatments for acute injuries, care needs to be taken regarding the stage of healing of the injury. Some phototherapy devices may emit a great deal of heat with the light, and this is contraindicated in the acute phase of healing. Clinicians need to be mindful of the stage of healing and to keep the "priority principle" in mind. Treating the injured tissues in order of significance, based on the three stages of healing, is paramount to successful outcomes. It can be common for clinicians to focus on pain reduction as a primary goal, however, in the presence of acute swelling, pain relief should be secondary. While it is important to reduce pain, the first priority in these situations is to eliminate swelling to improve circulation to the area.

As an illustration, consider an acute second degree ankle sprain with moderate swelling. If the site of the injury were treated first, a local increase in cellular activity from the photobiostimulation would result in an increase in inflammation and localized swelling at the site. The correct procedure would be to first treat the swelling to encourage lymphatic drainage and minimize the amount of local swelling from the acute injury. When treating the lymphatic system, it is necessary and prudent to treat proximal first, thereby opening and encouraging lymphatic flow from the distal area and evacuating swelling at site. As noted, treatment should begin at the most proximal site of drainage in the extremity and is known as "Oshiro's Principle."

The emitter should be applied with the "woodpecker" method, the probe does not move from the site, however there is rhythmic pressure done to alternately compress and release the lymph vessels. Treatment should begin at the most proxi-

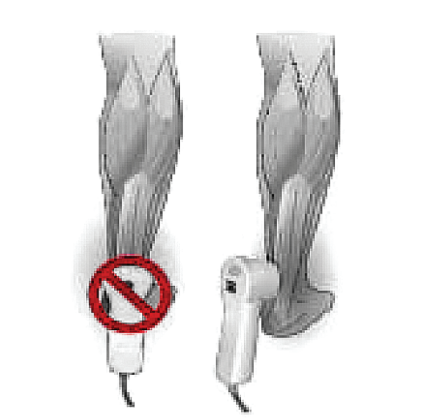

FIGURE 3. *Proper Laser Positioning for tendons at 45% to minimize reflection. (Copyright Medical Quant USA. Used with permission.)*

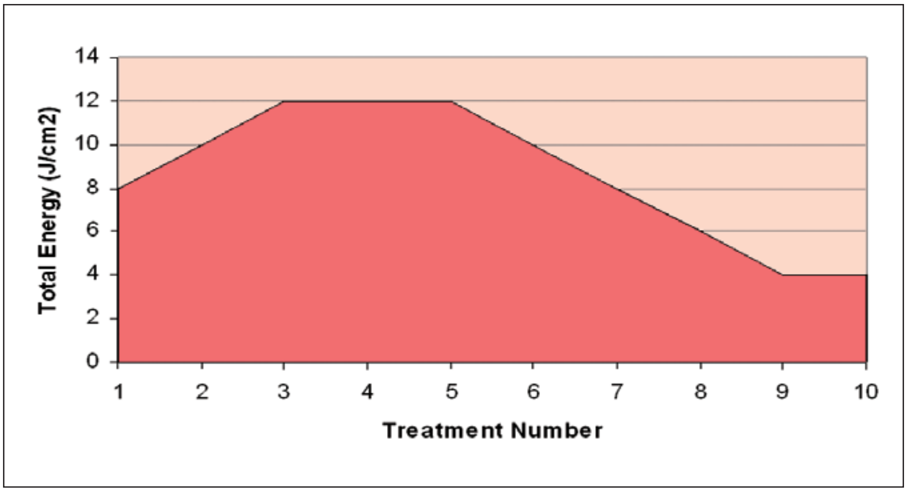

FIGURE 4. *Decrease in dosage as time and treatment progresses.*

mal lymphatic vessel—generally located near the trunk—followed by any additional proximal sites to the injury. Upon completion of all proximal treatment sites, direct treatment at the site of injury can be initiated. This will minimize the effects of lymphatic backup.

As the swelling reduces, proximal treatments will no longer be necessary and treatment can focus on tissue repair and pain reduction at the injury site. The use of cluster probes/emitters to stimulate the lymph vessels is highly recommended. CW doses for laser (coherent) and LED/IRED (non-coherent) range from 8 to 12 j/cm2 respectively. If using an SP laser, the use of extremely high frequencies (1000 Hz to 3000 Hz) for 3 to 5 minutes produces better results.

In some instance during treatment, there will be increases in swelling during rehabilitation. Depending on the extent of the swelling, treatment may again need to target the lymphatic system. This may sometimes be the case when dealing with lower extremity injuries that are complicated by vascular insuffiencies.

Tendon Injuries

The treatment of tendons requires a special technique that has clinically shown improved outcomes. While typical probe placement is done at a 90' angle to the target tissue, tendons—due to their dense composition, lack of pigmentation, and reflectivity—require that the probe be held at a 45' angle to the tissue to reduce reflection (see Figure 3). Doses of 8 j/cm2 are the most common for tendonitis.

Treatment of tendonitis with a superpulsed laser is slightly different than continuous wave lasers. The etiology of tendonitis is a combination of pain and inflammation. Therefore frequencies should specifically address the tissue response desired.

The application of the probe is similar to that of the continuous wave set-up, however super-pulsed probes are typically scanned evenly along the tendon itself. The dosimetry is done again in unit time however some treatments are done in "zones"—that is, the same area may be treated with several different frequencies. The first zone setting should be set between 3000 Hz to 5000 Hz (for inflammation) for approximately 2-4 minutes. The second zone uses a pulse repetition frequency between 5 Hz and 100 Hz for pain relief. It is importance to administer the higher frequency first.

Because tendonitis can be chronic in nature and there is prevalent oral anti-inflammatory use, it is one of the more difficult conditions for which to achieve consistent results. It can take several applications before any results may be seen.

Guidelines for Successful Outcomes

CW lasers need to follow dosimetry value curves in order to achieve beneficial therapeutic effects. This means that the initial dosage may need to be adjusted according to the type of treatment response. A treatment response is a measurable goal indicating a positive result in the treatment of an injury/illness from exposure to phototherapy. A treatment reaction is an exacerbation of a condition/illness resulting from an overexposure to phototherapy.

After the initial treatment, the athlete's condition should be reassessed to determine if there was a treatment reaction, a treatment response, or no response at all. If there was no response at all, dose should be increased by 2 joule increments at subsequent treatments until a treatment response or reaction is achieved.

A quick note about treating any type of chronic injury: occasionally, pain can increase following the first few treatments, indicating that the light energy may have "pushed" the chronic condition into an acute phase of healing. This is not always seen as a treatment reaction; however it may be necessary to decrease the dosage (by 2 joules) to obtain the desired treatment response if the symptoms persist.

Other Considerations and Guidelines for Successful Outcomes

There are several other considerations and recommendations that will help the clinician improve overall outcomes with phototherapy. As cells and tissues repair, the need for continued stimulation by the device is lessened. So what may initially have been a stimulatory dose may eventually become an inhibitory one. A common mistake novice clinicians make is to increase the time exposure or joules. In effect, the tissue's need has lessened since healing and repair has occurred. The dose should decrease as time and treatment progresses (see Figure 4).

Treatments at close intervals in the beginning (e.g. every other day or every third day for two weeks) have been found to be beneficial followed by progressively longer intervals (e.g. once a week for a few weeks). Experience shows that it is not disadvantageous to temporarily suspend treatment after a number of introductory sessions.

Certain considerations need to be taken into account when combining phototherapy with other physical agents. The use of heat or heating modalities should follow the application of phototherapy since the increase in blood circulation caused by heat may limit depth of penetration (as increased absorption by hemoglobin occurs at certain wavelengths). The use of ultrasound along with laser has shown little benefit and may actually counteract each other[23] (see Table 3).

Another consideration in the treatment of acute injuries with lasers is that during the acute phase, heat is especially contraindicated. Some devices, in particular, higher powered continuous wave devices, can cause a great deal of superficial heat. Direct treatment to acute injuries may increase localized swelling and impact overall rehabilitation time. These types of devices can be used systemically (to produce a tertiary effect, such as providing lymphatic draining) while avoiding direct treatment of acute injury sites.

A number of factors such as nutrition and blood supply can also affect the healing process. A rule of thumb is that sports injury takes a little more than half the ordinary healing time if the healing process is stimulated with laser therapy. A common problem is that the subjective discomfort in the injured area soon disappears and the individual wants to return to training immediately. It is essential that the injured are allowed to rest and that training be resumed gradually. Treatment should not be interrupted just because pain is gone. This only indicates progress in the recovery process—not complete healing.[24] Return to activity should be based on function rather than pain. Because laser therapy modulates pain, healing may not yet have occurred or completed.

Conclusion

Biophotostimulation–or phototherapy—modalities allow the athlete to regain the criteria for return, strength, and range of motion more successfully and in a shorter period of time. Short-term goal setting is imperative to proper return. Several plateaus should be successfully completed before full return to activity is allowed. Tennis elbow, for example, may be allowed an initial period of 5 minutes on alternate days, gradually increasing to full activity every other day. Patients are often so anxious to return to activity that they overdo, leading to a decrease in function with a rapid return to the results of inflammation. The goals of successful rehabilitation of the overuse syndrome are pain-free range of motion, strength, and endurance.[25] Phototherapy applications are helpful in meeting these goals efficiently. ■

Douglas Johnson, ATC, EES, CLS, is a certified athletic trainer with over 11 years of clinical/industrial experience. He attended Wayne State University and The University of Detroit Mercy where he earned a Summa Cum Lauds Bachelors of Science degree in Sports Medicine in 1994. He has worked extensively in the field of Occupation Medicine as the Assistant Regional Physical Therapy Director of Concentra Medical Centers Michigan Operations and as the therapy director of PrimeCare Medical Centers before co-founding a practice in 1996. Mr. Johnson is the co-owner of Sports and Industrial Rehab and founder of the Laser Center of Michigan. Working extensively with phototherapy technology, including the ML830 MedX Series 1100, PowerLaser 500, DuoLight 830, and the Solaris, he has been featured on FOX2 Healthworks, UPN50 Healthwatch, CBS WMEN5 Healthwatch, and ABC WXYZ7 Health Team Reports, and his articles that have appeared in NATA News, The Heritage Newspaper, and The Detroit News. He is the author of the article "Low Level Laser Therapy in the Treatment of Carpal Tunnel Syndrome" published in Athletic Therapy Today. His focus on phototherapy includes lectures throughout the Midwest, articles, and working on a phototherapy home study course.

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