Laser Therapy Applications in Sport Medicine.
Must know facts about laser-light-photo therapy.

Participation in high school sports helps promote a physically active lifestyle. High school sports participation has grown from an estimated 4 million participants during the 1971--72 school year to an estimated 7.2 million in 2005--06.[1] However, despite the documented health benefits of increased physical activity (e.g., weight management, improved self-esteem, and increased strength, endurance, and flexibility[2]), those who participate in athletics are at risk for sports-related injuries[3,4].

Participation in any sporting activity carries an inherent risk associated with the nature of the sport and the physical demands placed on the players. High school athletes account for an estimated 2 million injuries, 500,000 doctor visits, and 30,000 hospitalizations annually.[5] 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.

Athletes from all levels of participation, from student, collegiate, professional and recreational often suffer from injuries, and rapid recovery is desired for a speedy return to competition. 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 intention phase has a greater possibility of producing more scar tissue.[7]

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

Photostimulation 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 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 hence its biological effect depend upon the wavelength, whether the laser is super-pulsed, power output, the technical design of the apparatus, and 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 called 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. The 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 photoresponse, the last of which can be classified as either secondary or tertiary. [11]

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, the sensitivity of the cells are dependent on internal and external environment factors. [12]

The 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. [13]

It is the summation of primary, secondary and tertiary events that produce phototherapeutic activity. 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, in particular those of depth.

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.[14]

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. As described above, too much heat, such as in the case of a surgical powered laser, heat can be precarious to human tissue. A laser beam of MOP about 200 mW, carefully focused on an area of 1 cm^2 (power density 200 W/cm^2) for about 10 minutes is needed to produce first degree burns.[15]

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[16], Achilles' tendonitis[17], and shoulder tendonitis[18], medial and lateral epicondylitis[19], cervical pain[20] and wounds/abrasions[21]. 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. Further research is necessary to further validate the present findings and research studies should be conformed to the standards that have been established by WALT.[22]

Contraindications:

In 2006, many of the leading photoclinicans discussed the contraindications to phototherapy at the North American Association of Laser Therapy annual Congress in Toronto, Canada. 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.[23] In particular to sports medicine professionals was the addition of the treatment of children at the epiphysis of bones. Anti-inflammatory medication is commonly prescribed, however the use of NSAIDs is well documented to decrease the effectiveness of photobiostimulation.[24] Therefore light therapy is not indicated for patients who are on either oral or injectable anti-inflammatory medication therapies.

Specific Sports Injury Applications:

The treatment of muscle spasm and muscular pain is one 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) laser require a dosage 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/cm2 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 lasers emit beams that are always pulsed to set frequencies. 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 unit time (seconds), rather than joules. After assessing the patient's pain and spasticity of the muscle, set a frequency between 700 and 2500 Hz with the SP laser and apply the dose for approximately 2-3 minutes with mild overpressure. 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.

When electing phototherapy treatments for acute injuries, care needs to be taken in regarding what stage of healing the injury is in. 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 is paramount to successful outcomes; these stages can be identified by the stage of healing the injury is in. It can be common for clinicians to focus on pain reduction as a primary goal, however in the presence of acute swelling, pain relief would 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.

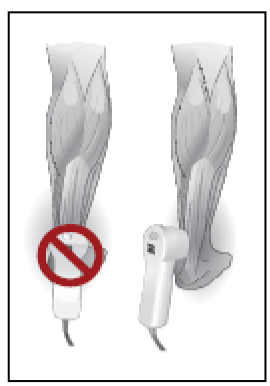
To illustrate this, consider an acute second degree ankle sprain with moderate swelling. If the site of the injury is treated first, a local increase in activity from the photobiostimulation would be created, resulting in an increase in inflammation and localized swelling at the site. Therefore it is necessary to first treat the swelling rather than the injury directly. This would 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, therefore opening and encouraging lymphatic flow from the distal area and to evacuate swelling at site. As noted, treatment should begin at the most proximal site of drainage in the extremity, this is "Oshiro's Principle".

The emitter should be applied with the "woodpecker" method, the probe does not move at the site, however there is rhythmic pressure done to alternately compress and release the lymph vessels. Treatment should begin at the most proximal lymphatic vessel, generally this will be 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 target. The use of multiprobes and clusters 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. The use of extremely high frequencies (1000 Hz to 3000 Hz) for 3 to 5 minutes produces better results with SP lasers.

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 complicated by vascular insuffiencies.



The treatment of tendons requires a special technique that clinically has shown improved outcomes. Typically probe placement is done at a 90' angle to the target. Tendons, due to their dense composition and lack of pigmentation, are reflective, so to minimize reflection, the probe is held at a 45' angle to the tissue. Doses of 8 j/cm2 are most common for tendonitis.

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 response the athlete had. 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 of phototherapy.

After the initial treatment, the athlete's condition should be reassessed to determine if there was a treatment reaction, a 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.

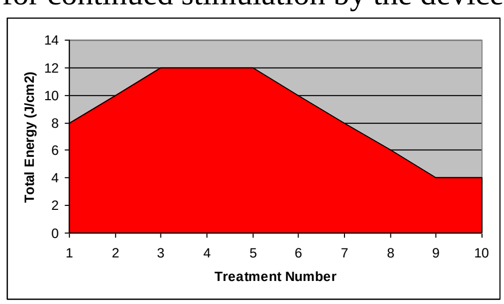
Treatment of tendonitis with a SP laser is slightly different than CW lasers. The etiology of tendonitis is a combination of pain and inflammation. Therefore frequencies should specifically address the tissue response desired.

The application of the probe is similar to that of the CW set-up, however typically SP probes are scanned evenly along the tendon itself. The dosimetry is done again in unit time; however there 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 of the 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 to achieve consistent results. It can take several applications before any results may be seen.

Other Considerations and Guidelines for Successful Outcomes:

There are several other considerations and recommendations that will help clinician improve their 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.



It has been shown to be beneficial to treat at close intervals in the beginning (e.g. every other day or every third day for two weeks) and then at longer and 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 combing phototherapy with other physical agents. The use of heat or heating modalities should follow the application of phototherapy. The increase in blood circulation caused by heat may limit depth of penetration as increase absorption by hemoglobin at certain wavelengths. The use of ultrasound and laser has shown little benefit and may actually counteract each other.[25]

In the acute phase, heat is especially contraindicated. Some devices, in particular higher powered CW 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 (produce a tertiary effect, such as providing lymphatic draining) and avoid direct treatment of acute injury sites.

A number of factors such as nutrition and blood supply can 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 he injured are be allowed to rest and that training be resumed gradually. Treatment should not be interrupted just because pain is gone. This is only the first sign of recovery.[26]

Finally, return to activity should not be based on pain, rather than function because laser modulates pain[27], but the healing may not have occurred. The modalities allow the athlete to regain the criteria for return, strength, and range of motion more successfully. 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.[28] Phototherapy applications are helpful in meeting these goals in a shorter amount of time.

Cryotherapy
Use phototherapy **after** due to vasoconstriction, it increases penetration

Heat therapies (including Hot Packs, Ultrasound, and Electrical Muscle Stimulation)
Use phototherapy **before,** increased blood flow causes increased absorption of light by hemoglobin resulting in decreased penetration

Phono / Iontophoresis
Use **before** steroid or anti-inflammatory agents, this modality negates the cellular effects of phototherapy, and should be done before

Manipulations / Mobilizations
May do **before or after,** depending on the specific goals of phototherapy

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Physical Therapy Director of Concentra Medical Centers Michigan Operations and as the therapy director of PrimeCare Medical Centers before beginning his practice with his partner in 1996. Johnson is the co-owner of Sports and Industrial Rehab and founder of the Laser Center of Michigan. Recently, Douglas Johnson was recognized as an expert in the field of phototherapy by NAALT (The North American Association for Laser Therapy) and was named to Multi Radiance Medical's Vice President of Clinical and Scientific Affairs. Douglas Johnson could be contacted at clinical@multiradiance.com

[1] National Federation of State High School Associations (NFHS). 2005--2006 High School Athletics Participation Survey. Indianapolis, IN: NHFS; 2006. Available at http://www.nfhs.org/sports.aspx.

[2] World Health Organization. Move for health: benefits of physical activity. Geneva, Switzerland: World Health Organization; 2006. Available at http://www.who.int/moveforhealth/advocacy/information_sheets/benefits/en/index.html. CDC. Guidelines for school and community programs to promote lifelong physical activity among young people. MMWR 1997;46 (No. RR-6.

[3] Gotsch K, Annest JL, Holmgreen P, Gilchrist J. Nonfatal sports- and recreation-related injuries treated in emergency departments---United States, July 2000--June 2001. MMWR 2002;51:736—40; Conn JM, Annest JL, Gilchrist J.

[4] Sports and recreation-related injury episodes in the U.S. population, 1997--1999. Inj Prev 2003;9:117--23.

[5] Powell JW, Barber-Foss KD. Injury patterns in selected high school sports: a review of the 1995--1997 seasons. J Athl Train 1999;34:277--84.

[6] NAALT standards 2003

[7] Principles of Athletic Training: Eighth Edition, Arnheim, Daniel and Prentice, William, 1993, Times-Mosby, p. 198-9.

[8] **The Science of Low-Power Laser Therapy** by Tina Karu, Gordon and Breach Science Publishers 1998 ISBN 90-5699-108-6

[9] Lubart, R., Friedmann, H., Faraggi, A. and Rochkind, S., (1991). Towards a mechanism of low energy phototherapy. Laser Therapy, 1991; 3: 11-13.

[10] Smith, Kendric C. (1991). The photobiological basis of low level laser radiation therapy. Laser Therapy, 1991; 3: 19-24.

[11] Primary, secondary and tertiary effects of phototherapy: a review Mary Dyson Emeritus Reader in the Biology of Tissue Repair, Kings College London (KCL), University of London, UK. Abstract from the 7th Congress of North American Association for Laser Therapy, Toronto, Canada, June, 2006

[12] Primary, secondary and tertiary effects of phototherapy: a review Mary Dyson Emeritus Reader in the Biology of Tissue Repair, Kings College London (KCL), University of London, UK. Abstract from the 7th Congress of North American Association for Laser Therapy, Toronto, Canada, June, 2006

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[14] *"Primary, secondary and tertiary effects of phototherapy: a review"* by Mary Dyson Emeritus Reader in the Biology of Tissue Repair, Kings College London (KCL), University of London, UK. Abstract from the 7th Congress of North American Association for Laser Therapy, Toronto, Canada, June, 2006

[15] **Low Level Laser Therapy as a Medical Treatment Modality by Pekka J. Pontinen**, 1992, ISBN 951-96632-0-7, Art Urpo Ltd., p. 143.

[16] J Clin Laser Med Surg. 2004 Apr;22(2):125-8. Low-level laser treatment can reduce edema in second degree ankle sprains. Stergioulas A. Faculty of Human Motion, University of Peloponnese, Attica, Greece. asterg@uop.gr

[17] Br J Sports Med. 2006 Jan;40(1):76-80; discussion 76-80. A randomized, placebo controlled trial of low level laser therapy for activated Achilles tendonitis with micro dialysis measurement of pretentious prostaglandin E2 concentrations. Bjordal JM, Lopes-Martins RA, Iversen VV. Physiotherapy Science, University of Bergen, Bergen, Norway. jmbjor@broadpark.no

[18] Scand J Rheumatol. 1989;18(6):427-31. Low power laser therapy of shoulder tendonitis. England S, Farrell AJ, Coppock JS, Struthers G, Bacon PA. Department of Rheumatology, Coventry & Warwickshire Hospital, UK.

[19] J Clin Laser Med Surg. 1998 Jun;16(3):145-51.
Treatment of medial and lateral epicondylitis--tennis and golfer's elbow--with low level laser therapy: a multicenter double blind, placebo-controlled clinical study on 324 patients. Simunovic Z, Trobonjaca T, Trobonjaca Z. Laser Center, Locarno, Switzerland. tzlatko@mamed.medri.hr

[20] Lasers Surg Med. 2004;35(3):229-35. Efficacy of 904 nm gallium arsenide low level laser therapy in the management of chronic myofascial pain in the neck: a double-blind and randomize-controlled trial. Gur A, Sarac AJ, Cevik R, Altindag O, Sarac S. Physical Medicine and Rehabilitation, School of Medicine, Dicle University, Diyarbakir, Turkey. alig@dicle.edu.tr

[21] "Low-Level Laser Therapy Facilitates Superficial Wound Healing in Humans: A Triple-Blind, Sham-Controlled Study", Hopkins, J. Ty, McLoda, Todd, Seegmiller, Jeff, Baxter, David, Journal of Athletic Training 2004;39(3):223-229, copyright NATA Inc, www.journalofathletictraining.org

[22]

http://www.walt.nu/WALT%20standard%20for%20conduct%20of%20randomized%20controlled%20trials.pdf

[23] Saltmarche, Anita and Carrol, Karen; Discussion of Contraindications, Abstract from the 7th Congress of North American Association for Laser Therapy, Toronto, Canada, June, 2006

[24] Lopes-Martins, R.A., Albertini, R., Lopes-Martins, P.S., DeCarvalho, F.A., Neto, H.C., Iversen, V.V. and Bjordal, J.M., Steroid Receptor Antagonisht Mifepristone Inhibits the Anti-Inflammatory Effect of Photoradiation. Photomed laser Surg, 2006. 24(2): p. 197-201.

[25] **The Laser Therapy Handbook by Jan Tuner and Lars Hode**, 2004, ISBN 91-631-1345-7, Prima Books, p. 93.

[26] **The Laser Therapy Handbook by Jan Tuner and Lars Hode**, 2004, ISBN 91-631-1345-7, Prima Books, p. 178.

[27] Laser-Accelerated INFLAMMATION/PAIN REDUCTION AND HEALING by Richard Martin, BS, CLT ; Practical PAIN MANAGEMENT, Nov/Dec 2003, p. 20-25.

[28] Clin Sports Med. 1987 Apr;6(2):427-66. Application of modalities in overuse syndromes. Gieck JH, Saliba EN. Department of Athletics, University of Virginia, Charlottesville.