Photobiomodulation Therapy

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Objectives

- By the end of this presentation, the learner will be able to:
  - Describe the therapeutic benefits associated with photobiomodulation therapy
  - Explain the physiological processes involved in photobiomodulation therapy
  - Identify clinical diagnoses appropriate for photobiomodulation therapy
  - Accurately determine dosing effective for optimal therapeutic benefit for numerous conditions

History

- 1967: Endre Mester discovered applying laser light to mice could a) cause hair to grow back quicker and b) stimulate wound healing in mice1
- Photobiomodulation therapy began as “low level laser therapy” as it started with ruby laser (694 nm) and HeNe lasers (633 nm)2
- “Laser” originated as an acronym for light amplification by stimulated emission of radiation1

Effects of photobiomodulation therapy

Reduce inflammation/edema through pro-inflammatory effects

Promote healing of wounds, deeper tissues and nerves

Treat neurological disorders/pain1-3

How photobiomodulation works

- Promotes *normal* cell function3
- Acts by inducing a photochemical reaction in the cell (also referred to as biostimulation or photobiomodulation)
  - Photon of light absorbed by chromophore → electron from chromopore becomes excited → jumps from low to high energy orbit → stored energy then used for tasks1

Optical Properties of Tissue

- When light strikes through biological tissue it is:
  - Absorbed
    - Most of light; energy states of molecules are quantized
  - Reflected
    - Produced by change in air and tissue refractive index
  - Scattered
    - Scattering behavior determines volume distribution of light intensity at the tissue
  - Further transmitted
- Absorption and scattering by molecules/structures primarily govern accepted penetration of light into tissue
  - Both become significantly less as wavelength gets longer1

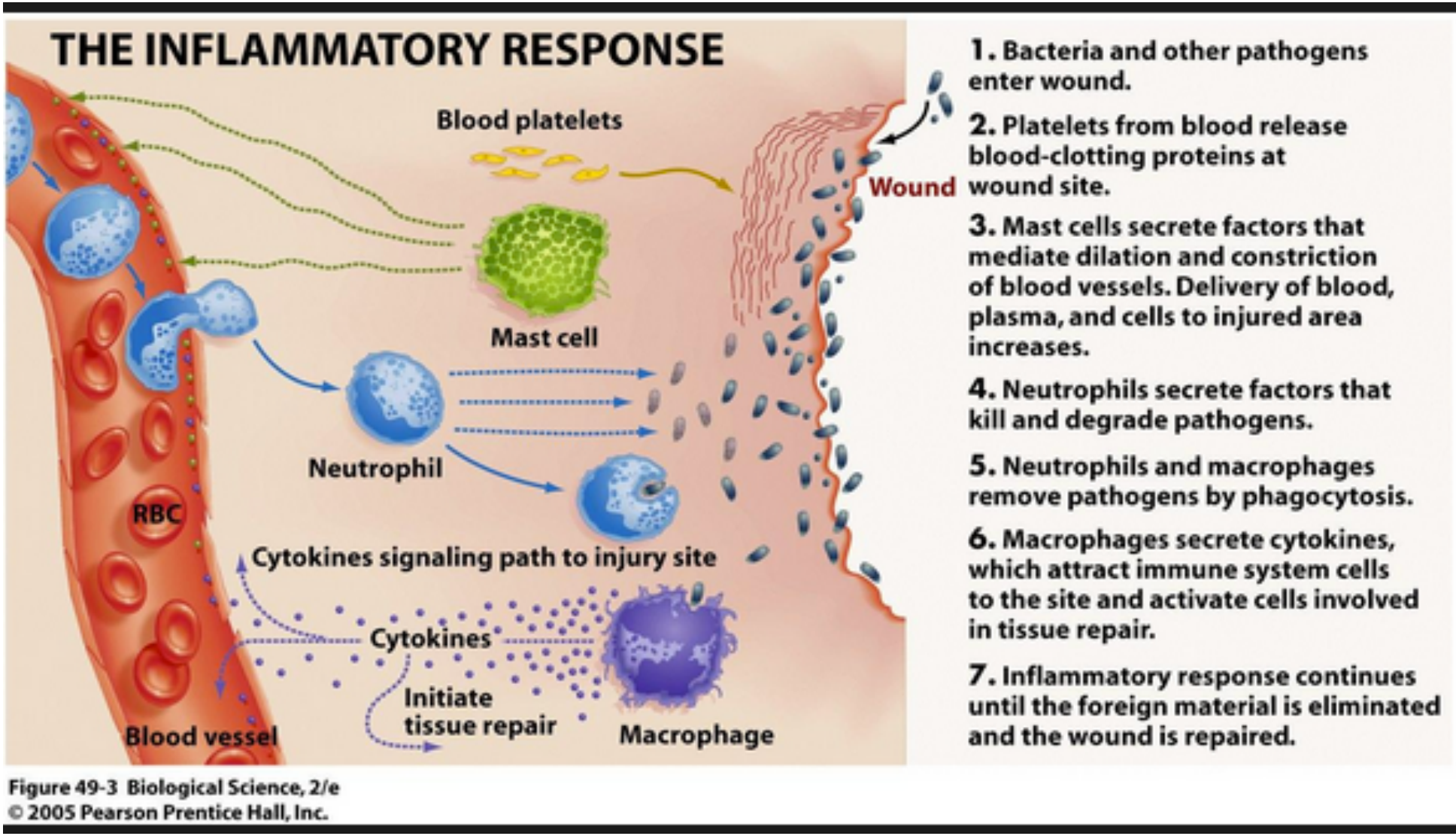


Figure 49-3 Biological Science, 2/e
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Mechanisms of LLLT

- Acts on mitochondria to release ATP via Cytochrome C oxidase (CCO)
  - Primary chromophore target for LLLT
  - Large transmembrane protein complex located on the inner membrane of the cell mitochondria
  - Component of electron transport chain which ultimately plays a role in the proton gradient used to produce ATP
  - Increased ATP = increased electron transport/energy transfer in the cell → increased cellular metabolism
- Produces free nitric oxide (NO)
  - NO (vasodilator) improves microcirculation in damaged tissue by delivering oxygen, vital sugars and salts while removing wastes1,2

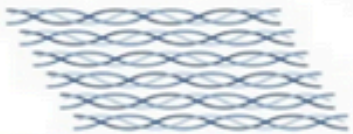
Mechanisms of LLLT (continued)

- Produces reactive oxygen species by increasing mitochondrial membrane potential (MMP)
  - Signals for inflammatory process
- Induction of transcription factors
  - Transcription factors then cause protein synthesis → increased cell proliferation & migration, modulation of cytokines, growth factors and inflammatory mediators and increase tissue oxygenation
- Triggers mast cell degeneration → leads to release of pro-inflammatory cytokine TNF-a from the cells → increased infiltration of tissues by leukocytes
- Enhances proliferation, maturation and motility of fibroblasts1,2

CLINICAL EFFECTS OF LASER THERAPY



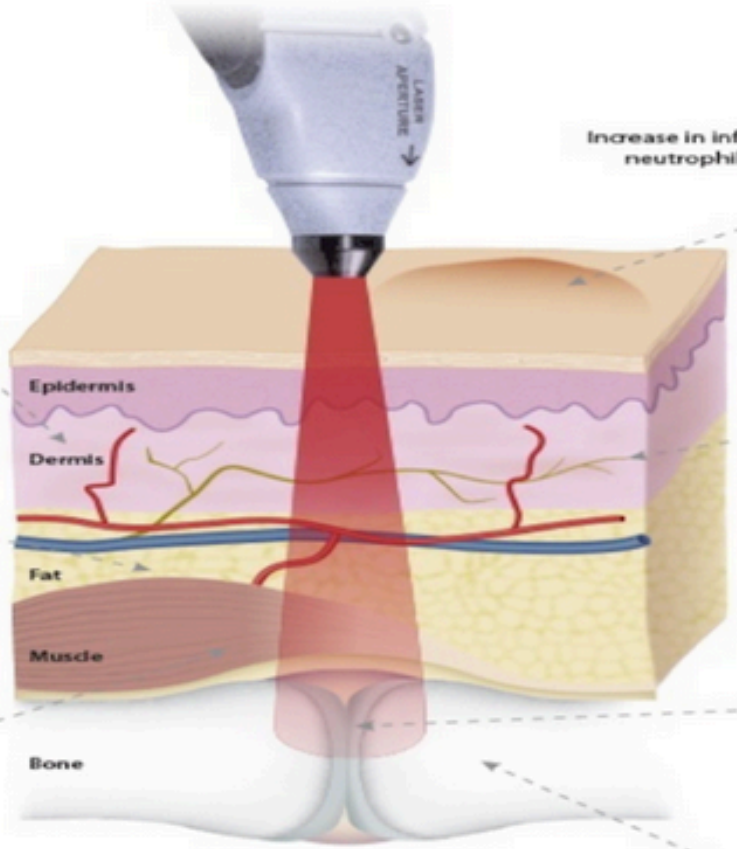
Angiogenesis & Neovascularization
An increase in oxygenated blood to the injured tissue accelerates tissue healing.

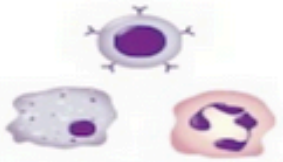


Collagen Production
Proper alignment and remodeling of collagen reduces internal scar formation and enhances tissue elasticity.



Muscle Regeneration & Muscle Atrophy
Repair of damaged muscle fibers and activation of myogenic satellite cells leads to regeneration of muscle tissue.

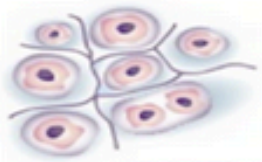




Inflammation & Edema
Increase in inflammatory mediators such as macrophages, neutrophils and lymphocytes accelerates and resolves the inflammatory process.



Nerve Regeneration
Proliferation of growth factors promotes neuronal sprouting and myelin formation for optimal nerve recovery.



Cartilage Production
Increase in chondrocyte and collagen production allows for improved cartilage deposition and joint function.



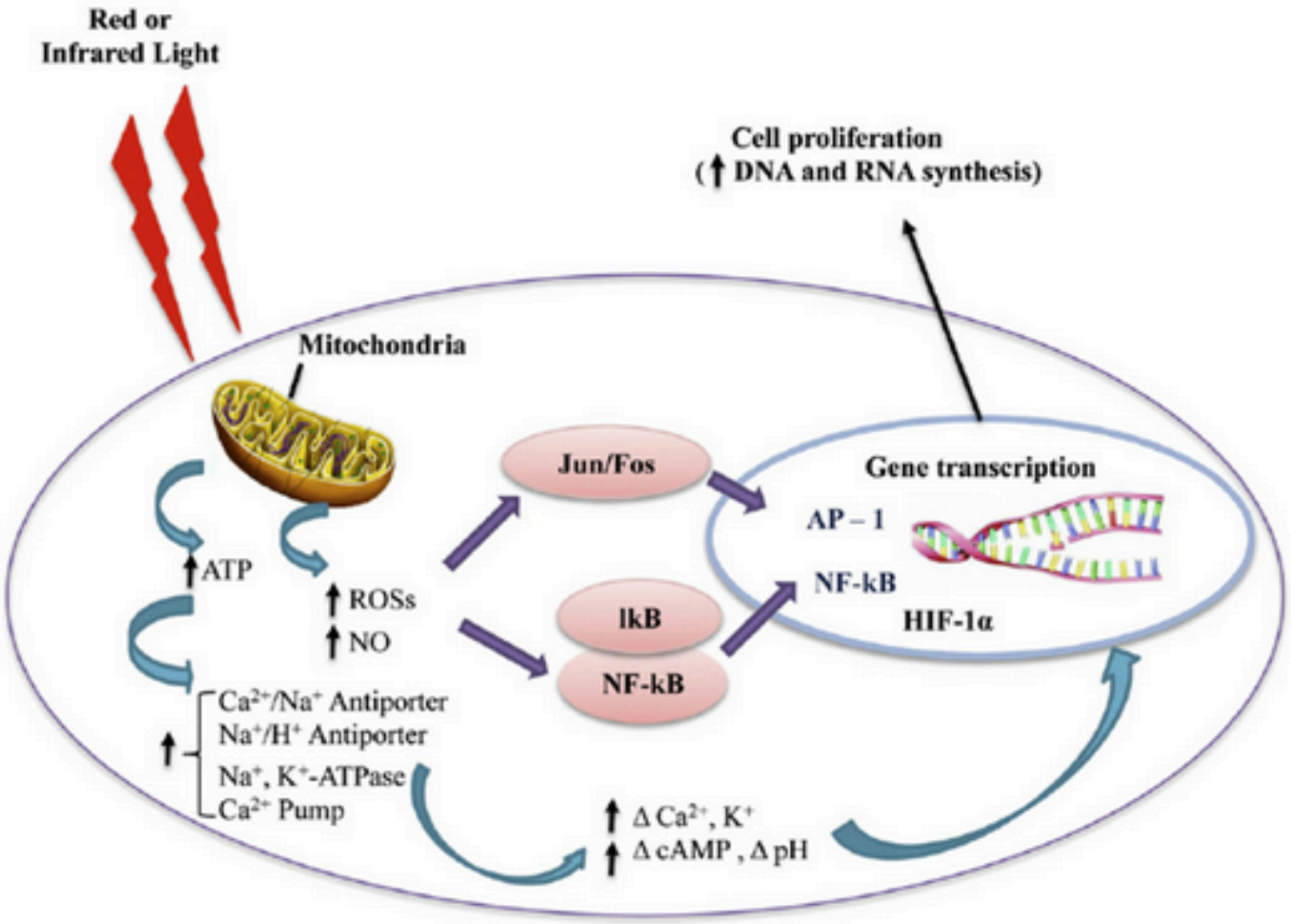
Bone Formation
Proliferation of osteocytes and remodeling of bone extracellular matrix results in accelerated bone repair.

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Class IV laser

- Functions in the near infrared spectrum
- Uses wavelengths between 650-1300 nm and power up to 20 W (can create heat, class III lasers do not)
- With the ability to deliver a clinically effective quantity of photons to cells deep within tissue, the Class IV laser widely expands conditions to be treated
- Class IV gives the clinician the ability to deliver adequate doses of light deep into tissue to reduce pain, reduce inflammation and accelerate healing4

Low-Level Laser Therapy



Chronic Pain & OA

- Pathogenesis of OA includes decreased articular cartilage, subchondral bone sclerosis, osteophyte development and chronic low-grade synovial inflammation
  - Biochemical properties relate to abnormal remodeling of the joint, spurred by inflammatory mediators
- Cytokines (interleukin 1, tumor necrosis factor, interleukin 8), bioactive lipids (prostagladin E), and pro inflammatory chemicals (nitric oxide) are seen in high concentration in osteoarthritic joints
- Recommended wavelength ranges from 600-1000 nm for analgesic and anti-inflammatory effects5

Neuropathic pain

- Systematic review by Andrade et al from 2016 analyzed 14 articles (10 animal studies, 4 human studies) to establish a therapeutic window for the effective use of LLLT for the treatment of neuropathic pain6
- Databases searched: Medilane/PubMed, Lilacs, Embase, Scielo, Scopus
- Results: LLLT for treatment of neuropathic pain has positive effects in controlling analgesia.
- Recommended parameters (infrared determined to be best)
  - Wavelength = 780 nm to 905 nm
  - Power = 70mW (most effective); though 30mW-450 mW has found significant results as well

Neuropathic pain (continued)

- Several researchers found LLLT as a nonpharmalogical alternative to peripheral neuropathy, due to the actions of biomodulation and antioxidant effects of the laser
- Strong link found between promotion of analgesia and reduction of bradykinin (pro-inflammatory neuropeptide responsible for sensitizing nociceptors) through modulation of the inflammatory process by the laser7,8
- LLLT has also been found to increase B-endorphin expression, further promoting pain reduction6

TMD

- RCT by Catao et al analyzed the effects of laser therapy on two groups 3x a week for 4 weeks: infrared and red laser treatment groups.
  - Infrared parameters: wavelength 830 nm, power 40 mW
  - Red laser parameters: wavelength 660 nm, power 30 mW
  - Both lasers used beam delivery system through direct skin contact with focus area of 0.20 cm2 appled at a dose of 4 J/cm2
- Infrared laser results: mouth opening improved from an average of 41.35 mm to an average of 46.16 mm (4.643 mm average improvement) and pain improved from an average of 8.4 using VAS to 1.4
- Red laser results: mouth opening improved from 46.34 mm to 50.05 mm (3.71 mm average improvement) and VAS from 8.1 to

Adhesive Capsulitis

- Authors searched Cochrane, PubMed, Embase, Cinahl and Pedro for relevant systematic reviews and RCTs and found five Cochrane reviews and 18 RCTs that included analysis of various interventions (oral meds, injections, physiotherapy, acupuncture arthrographic distension and SSNB) for adhesive capsulitis
- Conclusion: strong evidence for the effectiveness of steroid injections and laser therapy in short-term
  - Mid- term: moderate evidence for steroid injections
  - Moderate evidence favoring mobilization techniques for short and long term
  - Moderate evidence for SSNB over acupuncture in short term10

Lateral Epicondylitis

- A RCT by Lam and Cheing evaluated the effectiveness of 904 nm LLLT in management of lateral epicondylitis by randomly assigning 39 patients with lateral epicondylitis to active laser or sham irradiation group for a total of nine sessions
- Outcome measures included mechanical pain threshold, maximum grip strength and level of pain at maximum grip strength using VAS and subjective rating of DASH
- Results: significantly greater improvements in all outcome measures with the laser group except in two subsections of the DASH11

Safety and contraindications

- Eyes- do not aim laser beams into the eyes, everyone present should wear appropriate safety glasses
- Cancer- do not treat over the site of any known primary carcinoma or secondary metastasis unless pt is undergoing chem and LLLT can be used for side effects such as mucositis. LLLT can also be used for terminally-ill patients with cancer for palliative relief
- Pregnancy- do not treat directly over developing fetus
- Epileptics- be aware that low frequency pulsed visible light (<30 Hz) may trigger a seizure in photosensitive patients12

Definitions

- Energy = addition of individual energies of packets of light (photons); unit is Joules (J)
  - At any specific wavelength of light, every photon contains exactly the same amount of energy
- Irradiance = intensity of light; describes density of photons striking a given surface area per unit of time; W/cm2
  - Critically important for achieving therapeutic dose of light to target tissue
- Absorption and scattering characteristics = wavelength dependent
- To achieve clinically significant response, large number of photons must reach target tissue and be absorbed by target tissue chromopores
  - Deeper target tissues = greater radiances applied at skin surface

Definitions (continued)

- Watt= J/s; unit of power
- Dose = energy density (Joules/cm2)
- Area treated = (cm2)
- Time (sec) = Joules/power
- Joules = power (W) x time (seconds)
- Power Density (irradiance): W/cm2

Irradiance and dosing considerations

The condition being treated

- Considering how far below surface site of injury is and what types of tissue the light's energy must travel through

The absorption characteristics of any intervening tissues between the light source and the target tissue

- Skin, hair, fat and muscle must be considered
- Melanin = primary chromopore that acts as barrier to deeper tissue layers (treating through dark skin/hair is best at 980 nm)

The mechanism of delivery

- Off contact = lose 6% energy to reflection and to scatter with straight path
- On contact = tissue contact (minimizes light energy lose), tissue compression (lessens absorption and scatter loses by shortening distance light travels) and blanching (removes superficial blood from area, minimizing photonic lose from blood absorption)
- In conclusion: off contact will require more energy to deliver same number of photons

References

Chung et al. The nuts and bolts of low level laser (light) therapy. *Ann Biomed Eng*. 2012 February; 40(2): 516-533.

Hamblin M. Mechanisms and applications of the anti-inflammatory effects of photobiomodulation. *AIMS Biophys*. 2017; 4(3): 337-361.

Denegar C, Saliba E and Saliba S. Biological effects of laser therapy. *Therapuetic Modalities for Musculoskeletal Injuries, Third Edition. 2016*.

Deep Tissue Laser Therapy Medical Animation. *LightForce Lasers*. https://www.youtube.com/watch?v=dB9MIW9fduk

Dima et al. Review of literature on low level laser therapy benefits for nonpharmacological pain control in chronic pain

References

8. Chow et al. Inhibitory effects of laser irradiation on peripheral mammalian nerves and relevance to analgesic effects: a systematic review. *Photomed Laser Surg*. 2011; 29(6): 365-381.

9. Catao et al. Evaluation of the efficacy of low-level laser therapy (LLLT) in the treatment of temporomandibular disorders: a randomized controlled trial. *Revista CEFAC*. December 2013; 15(6): 1601-1608

10. Favejee M, Huisstede B and Koes B. Frozen shoulder: the effectiveness of conservative and surgical interventions- a systematic review. *Br J Sports Med*. 2011; 45: 49-56.

11. Lam L and Cheing G. Effects of 904-nm low-level laser therapy in the management of lateral epicondylitis: a randomized controlled trial. *Photomed and laser surg*. 2007; 25(2): 65-71.

12. Cotler H, Chow R, Hamblin M, Carroll J. The use of low level laser therapy (LLLT) for musculoskeletal pain. *MOJ Orthop Rheumatol*. 2015; 2(5): 1-7.

13. Photobiomodulation Therapy. Key Factors for Successful Treatment. *Companion*