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Health Benefits of Far Infrared Ray

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Abstract

Far infrared ray is a subdivision of infrared band in the electromagnetic spectrum and with a wavelength range from 4 - 1000 micrometer. At 4-14 micrometer, it is most beneficial to the health of humans. Far infrared ray enhances cell and tissue response and yields therapeutic effect in tissue regeneration, chronic pain management, vasodilation, improved blood circulation, and arthritis. The aim of this review is to emphasize the health benefits of far infrared ray. These benefits are based on the biophysical mechanism of far infrared ray interaction with living cells, which leads to altering of cell membrane potential and mitochondrial metabolism. There are natural (sun, warm springs) and artificial sources of far infrared. Artificial sources are usually commercialized sources of far- infrared ray which include ceramics, and special lamps for delivering pure far-infrared ray. Further technological advancement has enabled new methodology for utilizing far-infrared ray in rhyolite, ceramic nanoparticles impregnated into fabrics. These diverse sources are essentially used to deliver far infrared ray in different combinational models, and it is an alternative way to attain tissue regeneration, arthritis and chronic pain management, vasodilation, improved blood circulation and development of specialized oven in laboratory instrumentation.

Key words: Health, benefits, far infrared ray, infrared band, electromagnetic spectrum, wavelength.

Introduction

The sun as a natural source of electromagnetic radiation to the earth and all living organism are exposed to it and also experience the beneficial and adverse effects of it at all levels, starting from the sub-cellular organelle and ends with the whole body (Vatansever and Hamblin, 2012). Infrared radiation is a band of energy in the electromagnetic spectrum with wavelength range from 0.750 μm –1000 μm , frequency range from 430 THz–0.3THz, and photon energy range from 1.7eV– 1.24meV (Miller, 1994). Infrared radiation has been effectively applied to treat or ease certain medical conditions. In the infrared radiation bands, only far-infrared transfers energy purely in the form of heat and resonance energy and can be perceived by the thermoreceptors in human skin as radiant heat. Not only is far infrared radiation absorbed by the human body but it is also emitted by the body in the form of black body radiation output peak at 9.4 μm . Far infrared ray with a wavelength of 4 μm - 1000 μm , a frequency range of 20THz – 0.3THz, and photon energy range from 6.41meV -1.7eV, with technological advancement and the deployment of far-infrared ray the benefits of its radiation to humans have become widened (Wang *et al.*,2010).

Nowadays, specialty far-infrared emitting heat lamps and garments made up of filaments (fibers) impregnated with far infrared ray emitting



nanoparticles are becoming used to deliver these thermal radiation effects (Liang *et al.*, 2008).

Electromagnetic Radiation Spectrum

Electromagnetic radiation consists of electromagnetic waves which can be characterized by the frequency, wavelength or the photon energy

of their oscillations, which determines their position in the electromagnetic spectrum. Which is in order of increasing frequency and decreasing wavelength: radio waves (short wave, medium wave and long wave), microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays (Haynes, 2011).

Table 1: Electromagnetic wave bands (Haynes, 2011)

Electromagnetic radiation spectrum is categorized using the properties of a wave, which are wavelength, frequency and photon energy. Gamma radiation has the shortest wavelength and radio waves has the longest

Name	Wavelength	Frequency (Hz)	Photon Energy (eV)
Gamma ray	Less than 0.01nm	more than 30 EHz	124 keV – 300+ GeV
X-ray	0.01 nm – 10 nm	30 EHz – 30 PHz	124 eV – 124 keV
Ultraviolet	10 nm – 400 nm	30 PHz – 790 THz	3.3 eV – 124 eV
Visible ray	400 nm–700 nm	790 THz – 430 THz	1.7 eV – 3.3 eV
Infrared	700 nm – 1 mm	430 THz – 300 GHz	1.24 meV – 1.7 eV
Microwave	1 mm – 1 meter	300 GHz – 300 MHz	1.24 μeV – 1.24 meV
Radio Wave	1 meter – 100,000 km	300 MHz – 3 Hz	12.4 feV – 1.24 meV

wavelength. Wavelength is inversely proportional to the frequency and photon energy of the wave (Haynes, 2011).

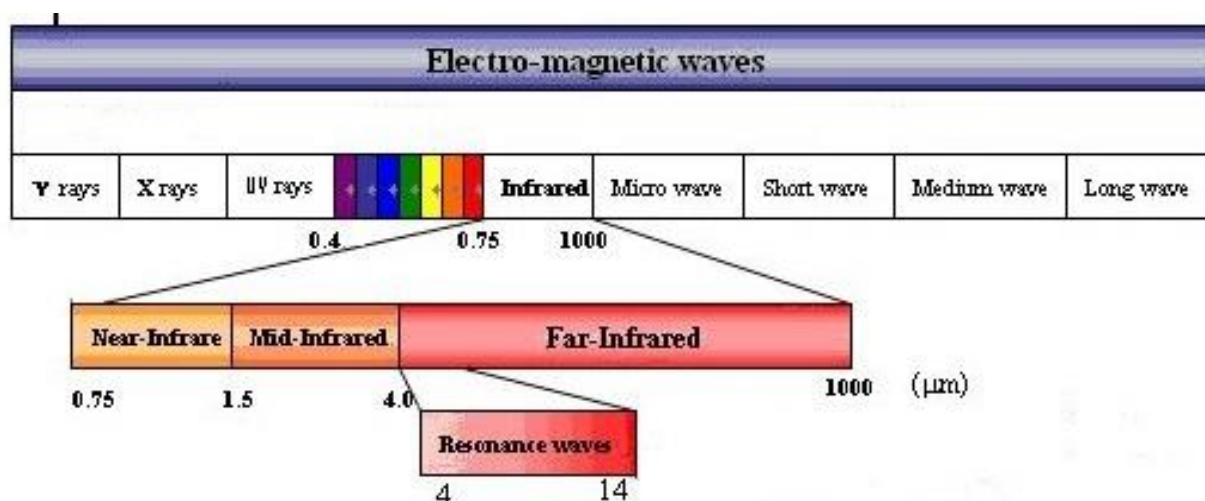


Figure 1: Classes of electromagnetic waves by wavelength (Yamashita, 2012)

The electromagnetic spectrum is divided into bands with a highlight on the region of infrared and its

subdivision of near-infrared, mid-infrared, and far-infrared with the resonance wave of 4-14 μm, a

region in the far-infrared which is of immense benefit to human considering the peak absorption/radiation wavelength 9.5 μm for humans (Yamashita, 2012).

Sources of Far Infrared Radiation

There are both natural and artificial sources of far-infrared ray. Natural sources includes sunlight, human body and rhyolite (79% silica) and artificial sources includes special lamps (WS TY-301R®, WS Far Infrared Medical Technology Co., Ltd., Taipei, Taiwan) (Vatansever and Hamblin, 2012) and

ceramics micro-sized particles composed of numerous elemental ingredients, including calcium (Ca), zirconium (Zr), sulfur (S), silicon (Si), aluminum (Al), magnesium(Mg), iron (Fe), oxygen (O), and carbon (C), which were developed by the biomaterials laboratory of Taipei Medical University, Taiwan (Leung *et al.*, 2012; Lueng *et al.*,2011).

Boron-silicate mineral, tourmaline (known as a gemstone in its crystalline form) when milled into fine powders also emits far infrared ray and the characteristics of the far –infrared ray emission depend on the particle size (Meng *et al.*,2010).

Ionizing and Non-Ionizing Electromagnetic wave

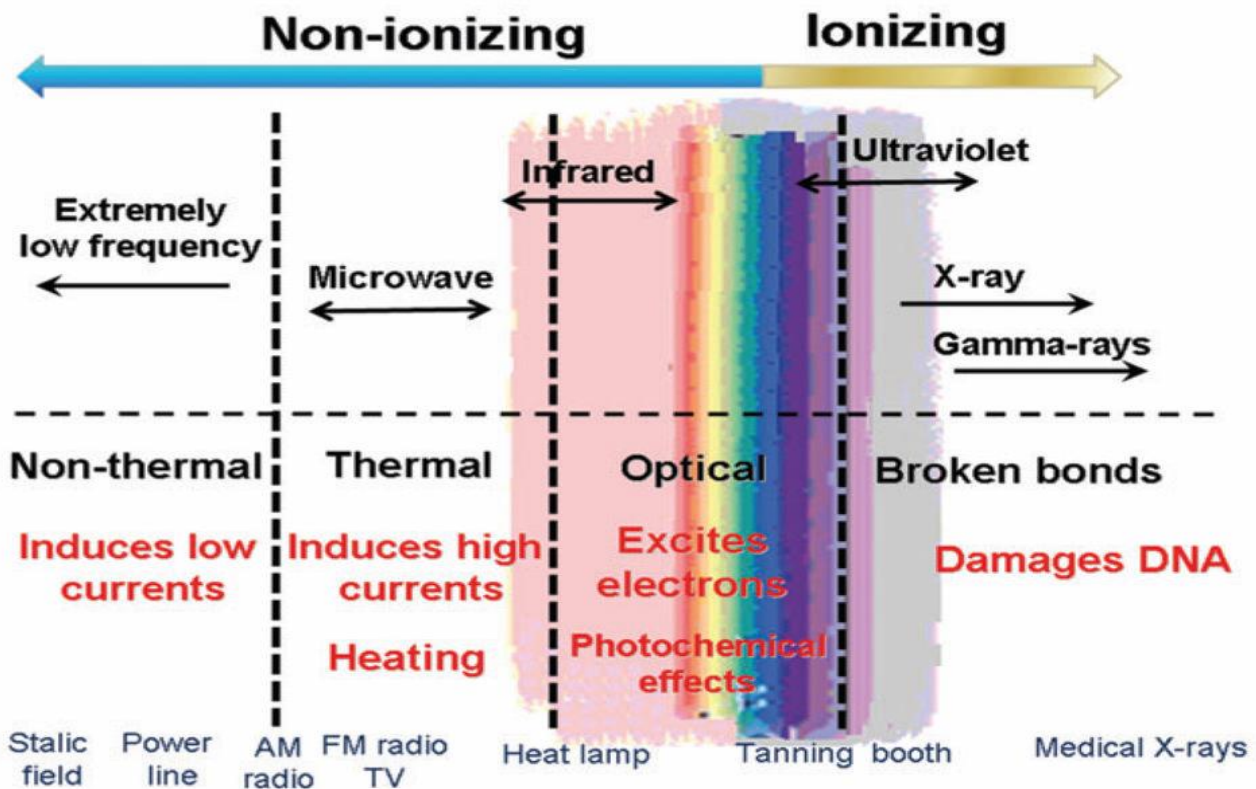


Figure 2: The spectrum of electromagnetic radiation and some biological changes it may induce (Ozdemir and Kargi, 2011).

The electromagnetic spectrum is classified into two regions which are ionizing and the non-ionizing radiation. Ionizing radiations are extremely high frequency electromagnetic waves (X-rays and gamma rays), which have enough photon energy to produce ionization by breaking the atomic bonds that hold molecules in cells together. Non-ionizing (NIR) is a term for that part of the electromagnetic

spectrum which has photon energies too weak to break atomic bonds. They include ultraviolet radiation, infrared radiation, radiofrequency and microwave fields (Ozdemir and Kargi, 2011).

NIR cannot cause ionization. However, it has been shown to produce other biological effects, for



instance by heating, altering chemical reactions or inducing electrical voltage in tissues and cells.

Biological Effects and Mechanism of Far Infrared ray.

FIR application in medicine requires understanding and knowledge of the interactions of electromagnetic radiation at FIR range with biological structures (including cells, cell membranes, cell fluids – especially water, DNA/proteins) and functioning of the living systems in general. At the cellular level, the underlying biophysical mechanisms of the interaction of electromagnetic radiation with living cells can be framed in terms of altered cell membrane potentials and altered mitochondrial metabolism (Sheppard *et al.*, 2008).

Biochemical Bond and Far Infrared Ray

Molecular bonds, at level of vibration absorb far infrared ray energy photons with quantum energy level (6.41meV -1.7eV). There are six vibration modes covering symmetric and antisymmetric, stretching, scissoring, rocking, wagging and twisting (Lee *et al.*, 2008). Considering the high concentration of water in biological systems, association of water molecules with ions (solvation effect), the dielectric properties of the water and the large dipole moment that this effect generates, this will be a dominant factor in biological solutions.

At lower frequencies water molecules are able to rotate freely in an oscillating electric field with little or almost no energy loss. However, if the frequency of the electric field reaches 10^8 Hz levels, the rotational mode becomes hindered (due to “dielectric friction” effect) and the absorbed energy starts dissipating by collision or nearest neighbor interactions in the media (Sheppard *et al.*, 2008). The dielectric relaxation of water at 310 K is around 25 GHz where the rotational response of the dipoles to the electromagnetic field is spread over a broad frequency range. In living systems, in addition to the water molecules association with the electromagnetic field and effects of that, one has to consider the “meso-structure” effect where proteins and charged groups (located at specific sites on the

proteins) are crucial for the overall biological activity (Inoué and Kabaya, 1989).

These specifically located charged groups associate with the water molecules and by doing this influence the dielectric behavior of the whole molecular-assembly, which in turn effects its biologic functioning. Thus, the dielectric properties of tissues (even at cellular level) depend on and vary with the water content (Yoo *et al.*, 2002). In addition, the relaxation of these molecular “meso-structures” can show variations with frequency. For these reasons, water content is a critical factor in the interaction between far-infrared ray and living organisms (Inoué and Kabaya, 1989).

The dynamics of water-clusters has attracted considerable interest since there is a noticeable difference with respect to the dynamics of bulk-liquid-water, and this have significant implications in biological environments. Local changes in the molecular environment (caused by solvation or confinement) are shown to affect substantially the translational and vibrational modes in far-infrared frequency range. It is found that water cluster size and temperature affect the far-infrared absorption spectrum significantly (Sheppard *et al.*, 2008). There is another mechanism of far-infrared ray effects on living systems, that is obtainable from ceramics nanoparticle and fabrics emitting far-infrared ray.

This basically at same mode of operation with low level light therapy (LLLT). It involves absorption of red ray/IR light by mitochondrial chromophores such as cytochrome c oxidase (CCO, unit IV of the mitochondrial respiratory chain) (Chung *et al.*, 2012). This photon absorption activates the enzyme by photo-dissociating the inhibitory molecule, nitric oxide (NO), from the copper B (CuB) site (Lane, 2006). This loss of NO allows electron transport, oxygen consumption, and adenosine triphosphate (ATP) to rapidly increase and results in a marked rise in mitochondrial membrane potential (MMP) that gives rise to a brief burst of ROS (Chen *et al.*, 2009). Signaling pathways are activated by ATP, NO, and ROS and these lead to activation of transcription factors (such as NF- κ B) that lead to the

long-term effects on tissue (*Chen et al., 2011; Huang et al., 2009*).

Far-infrared ray also utilizes the nanostructured water layers, these are thin (nano meters) layers of water that build up on hydrophobic surfaces such as cellular membranes, and they can be considered as “concentrated water” (*Sommer et al., 2011; Sommer et al., 2008*). The relatively small amounts of vibrational energy delivered by non-heating FIR perturbs the structure of the membrane underlying the nanoscopic water layer without bulk heating. Small perturbations in membrane structure could have big effects at the cell level if the membrane contains an ion channel. Many kinds of ion channels for both cations and anions are present in all cell membranes, but are particularly common in mitochondrial membranes, both inner and outer (*Ravna and Sylte, 2012; Perez-Pinzon et al., 2012*). Mitochondrial ion channels, particularly calcium channels open by non-heating FIR, thus increasing mitochondrial respiration (*Calì et al., 2012*).

Application of Far Infrared Ray

Far-infrared ray is used as a therapeutic model and the wavelength is too long to be perceived by the eyes. However, the body experiences its energy as a gentle radiant heat or non-heat radiation which can penetrate up to 2.3 inches beneath the skin. FIR energy is sufficient to exert rotational and vibrational modes of motion in bonds forming the molecules (including the water molecules) as well as resonate with cellular frequencies to yield its biological effects body (*Vatansever and Hamblin, 2012*).

In depressed patients with insomnia, it was observed that the damaging effect of malondialdehyde (MDA) was reduced upon irradiation with far-infrared ray, in which serotonin increased but MDA decreased after the introduction of FIR. These observations indicate that the serotonin pathway is involved in the pathophysiological mechanism responsible for the damaging effects of MDA on depressed patients with insomnia (*Chang et al., 2009*).

Successive far-infrared irradiation treatment at 15 minutes a day for two weeks improves cardiac arrhythmias in chronic heart failure (CHF) patients,

because ventricular arrhythmias are an important therapeutic target in CHF (*Kihara et al., 2004*). *Masuda et al.* (2004) shows the relationship between far-infrared ray and oxidative stress. Far-infrared therapy improves impaired vascular endothelial function in patients with coronary risk factors by decreasing urinary 8-epi-prostaglandin F(2alpha) (PGF(2alpha) levels as a marker of oxidative stress.

In Fibromyalgia syndrome (FMS)- a chronic syndrome characterized by widespread pain with tenderness, far-infrared ray therapy is effective for the treatment of fibromyalgia syndrome (*Matsushita et al., 2008*). Patients received far-infrared therapy once per day for 2 or 5 days/week. The patients were placed in the supine or sitting position in a far infrared-ray dry sauna maintained at an even temperature of 60 degrees C for 15 minutes, and then transferred to a room maintained at 26-27⁰C where they were covered with a blanket from the neck down to keep them warm for 30 minutes. Reductions in subjective pain and symptoms were determined using the pain visual analog scale (VAS) and fibromyalgia impact questionnaire (FIQ) (*Matsushita et al., 2008*).

Allergic Rhinitis (AR) is the sixth most common chronic illness worldwide, with symptoms of eye itching, nasal itching, nasal stuffiness, rhinorrhea and sneezing. Upon far-infrared utilization the symptoms were significantly improved and far-infrared irradiation serves as a novel therapy (*Hu and Li, 2007*).

Cancer cells irradiated with far-infrared radiation (FIR) of wavelengths between 4 and 20 micrometer with a peak of 7-12 micrometer, and found that FIR caused different inhibiting effects to five human cancer cell lines, namely A431 (vulva), HSC3 (tongue), Sa3 (gingiva), A549 (lung), and MCF7 (breast). The gene expression concerned to the inhibition effect by FIR were analyzed. In consequence, basal expression level of HSP70A mRNA was higher in A431 and MCF7 cells than in the FIR-sensitive HSC3, Sa3, and A549 cells. Also, the over expression of HSP70 inhibited, FIR-induced growth arrest in HSC3 cells, and an HSP70 siRNA inhibited the proliferation of A431 cells by



irradiation with FIR. Hence FIR suppresses the proliferation of some cancer cells which is controlled by the basal expression level of heat shock protein (HSP) 70A. FIR is an effective medical treatment for some cancer cells which have a low level of HSP70. (Ishibashi *et al.*, 2008). The boron-silicate mineral, tourmaline powder, a source of far infrared ray has been applied to the skin with the aim of increasing blood flow (Yoo *et al.*, 2002).

Chemotherapy (M-VAC) combined with far-infrared ray with mild hyperthermia, which potentiates the anticancer effect and reduces adverse drug reactions such as gastrointestinal symptoms, is a useful and safe method for the treatment of advanced transitional cell carcinoma of the urothelium (Yamada *et al.*, 2009).

Laboratory Application

In order to clarify the effects of the FIR energy radiation on the living body at the level of a cell and animal, the far infrared ray incubator for cell culture and animal raising apparatus was developed utilizing the valid ceramics as the rhyolite and the pure black that resemble effects as the ideal black body are well known (Yamashita, 2012). The CO₂ incubator must be exactly controlled particularly the

temperature inside of the incubator at $37\pm 0.5^{\circ}\text{C}$. Therefore, though the water jacket of about 40 liters is equipped for the suppression of heat loss, the equipment of incubator becomes solid and heavy. Then, 0.5% CO₂ gas needs to be supplied into the incubator to activate the culture cell breathing. Still more, the gas of 0.5% CO₂ in air must be supplied through the water layer in order to keep the humidity near 100%. The heating system was changed to FIR panel heater for keeping the temperature in the incubator at $37\pm 0.5^{\circ}\text{C}$. The five face at up, down, both side and behind in the incubator except the front glass were coated with the valid ceramics as the rhyolite and the pure black close to black body for raising the efficiency of FIR radiation. Then all shelves were also coated with the same ceramics. (Yamashita, 2012). Still more, the water jacket was change to the simple insulation, because the FIR energy directly and instantly heats the surface of objects even if the air and space lie between the surface of incubator and the objects. As a result, the light and compact CO₂ incubator that can continuously radiate the FIR energy for 24 hours was developed with a great success. The effect of the FIR energy radiation on the culture cells become possible utilizing the same type of CO₂ incubator without remodeling as control.



Figure 2: Far Infrared Ray CO₂ incubator (Yamashita, 2012)

Then, the FIR animal raising apparatus with same FIR radiating system of the FIR CO₂ incubator to control the temperature inside at 20-40°C which breakdown any smell chemical products by photo-degradation with the light catalyst of TiO₂. The FIR animal raising apparatus has the two chambers with

the upper chamber being coated with the valid ceramics as the rhyolite and the lower chamber is no coating. So, the strict comparative experiments on the effect of FIR energy radiation on animals become also possible by using the FIR animal raising apparatus.



Figure 3: Far Infrared Ray animal raising apparatus (Yamashita, 2012)

Methods of Far Infrared Ray Utilization

Garments, buttons, and disc manufactured of far-infrared ray emitting ceramic material have been applied to the human body, blanket containing discs has been reported to improve quality of sleep and single discs were applied for women who

encountered difficulty in producing sufficient breast milk during lactation (Ogita *et al.*, 1990). Hand gloves have been made out of FIR emitting fabrics and there have been reports that these gloves can be used to treat arthritis of the hands and Raynaud's syndrome (Ko *et al.*, 2002).

4.1 Far Infrared Ray Devices



Figure 4: (A) WS TY-101N® and (B)WS TY-301R® (C) WS Far Infrared Medical Technology Co., Ltd., Taipei, Taiwan (Hsu *et al.*, 2012)

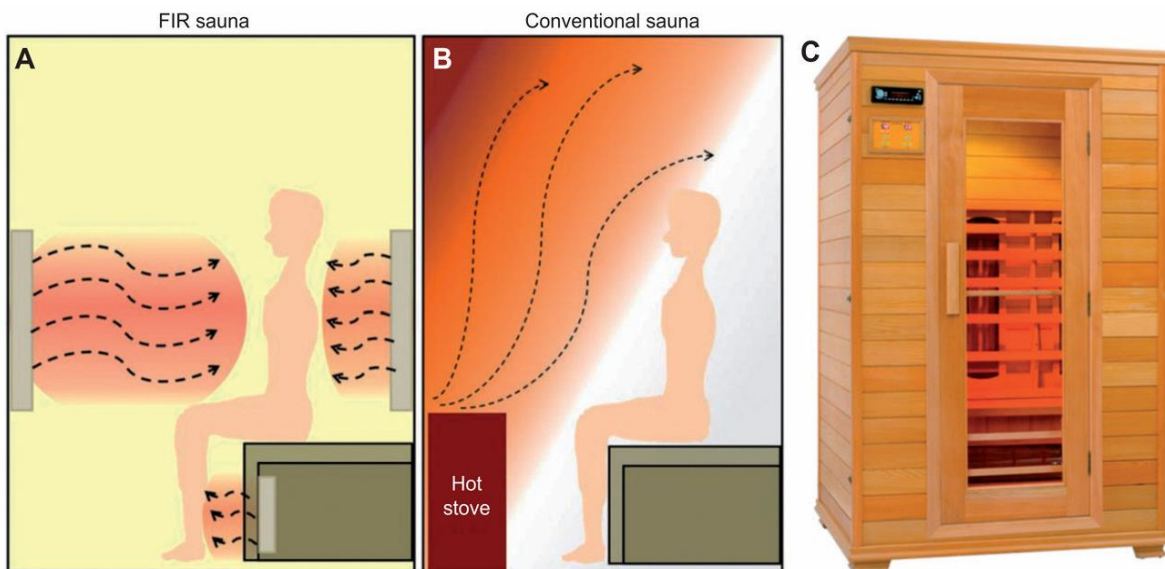


Figure 5: Cabin incorporating FIR emitting “cold” unit(s) (Anhui Hi-Tech Electronic Commerce Co., Ltd., Hefei, China) (Oosterveld *et al.*,2009).

Conclusion

With real thermal and non –thermal FIR significant biological effects, then the possible future applications are wide ranging. Not only could

bandages and dressings made out of FIR emitting fabrics be applied for many medical conditions and injuries or discomfort that require healing, but there is a large potential market in lifestyle enhancing applications. Garments may be manufactured for



performance enhancing apparel in both leisure activities and competitive sports areas. Cold weather apparel would perform better by incorporating FIR emitting capability and sleeping environments could be improved by bedding that emitting Far Infrared Ray.

Recommendation

With the potentials of far infrared ray, more interrelated and coordinated collaboration should be encouraged in development of diagnostic, preventive and therapeutics in healthcare systems.

Conflict of interest: There is no conflict of interest associated with this work”.

References

- Cali, T., Ottolini, D. and Brini, M. (2012) Mitochondrial Ca⁽²⁺⁾ as a key regulator of mitochondrial activities. *Advances in Experimental Medicine and Biology*; **942**:53–73.
- Chang, Y., Liu, Y.P. and Liu, C.F. (2009). The effect on serotonin and MDA levels in depressed patients with insomnia when far-infrared rays are applied to acupoints *American Journal of Chinese Medicine*.37(5):837-42.
- Chen, A.C.H., Huang, Y.Y., Arany, P.R. and Hamblin, M.R. (2009) Role of reactive oxygen species in low level light therapy. *Society of Photographic Instrumentation Engineers*; **7165(02)**:200-219.
- Chen, A.C., Arany, P.R., Huang, Y.Y., *et al.* (2011) Low-level laser therapy activates NF-κB via generation of reactive oxygen species in mouse embryonic fibroblasts. *Public Library of Science One*; **6(7)**:2189-2199.
- Chung, H., Dai, T., Sharma, S.K., *et al.* (2012) The nuts and bolts of low level laser (light) therapy. *Annals of Biomedical Engineering*; **40(2)**:516–533.
- Haynes, K., William M. (2011). *Chemical Rubber Company Handbook of Chemistry and Physics* (92nd Edition.). Chemical Rubber Company Press:233.
- Hu, K. H. and Li, W. T. (2007) Clinical effects of far-infrared therapy in patients with allergic rhinitis. *Engineering in Medicine and Biology Society*;2007: 1479-1482.
- Huang, Y.Y., Chen, A.C., Carroll, J. D., Hamblin, M.R. (2009) Biphasic dose response in low level light therapy. *Dose Response*; **7(4)**:358–383.
- Hsu, Y.H., Chen, Y.C., Chen, T.H., *et al.* (2012) Far-infrared therapy induces the nuclear translocation of PLZF which inhibits VEGF-induced proliferation in human umbilical vein endothelial cells. *Public Library of Science One*; **7(1)**:306-374.
- Inoué, S. and Kabaya, M. (1989) Biological activities caused by far-infrared radiation. *International Journal of Biometeorology*; **33(3)**:145–150.
- Ishibashi, J. Yamashita, K., Ishikawa, T. *et al.* (2008). The effects inhibiting the proliferation of cancer cells by far-infrared radiation are controlled by the basal expression level of heat shock protein 70A. *Medical Oncology*; **25(2)**:229-237.
- Kihara, T., Biro, S, Ikeda, Y, *et al.* (2004) Effects of repeated sauna treatment on ventricular arrhythmias in patients with chronic heart failure. *Circulation Journal*; **68(12)**:1146-1151.
- Ko, G.D. and Berbrayer, D. (2002) Effect of ceramic-impregnated thermoflow gloves on patients with Raynaud’s syndrome: randomized, placebo-controlled study. *Alternative Medicine Review*; **7(4)**:328–335.
- Lane, N. (2006). Cell biology: power games. *Nature*; **443(7114)**:901–903.
- Lee, M.S., Baletto, F., Kanhere, D.G. and Scandolo, S. (2008) Far-infrared absorption of water clusters by first principles molecular dynamics. *Journal of Chemical Physics*; **128(21)**:2145-2106.
- Leung, T. K., Lee, C.M., Tsai, S.Y. *et al.* (2011). A pilot study of ceramic powder far-infrared ray irradiation(cFIR) on physiology: observation of cell cultures and amphibian skeletal muscle. *Chinese Journal of Physiology*; **54**: 247-254.
- Leung, T.K., Chan, C.F., Lai, P.S., *et al.* (2012). Inhibitory effects of far-infrared irradiation generated by ceramic material on murine

- melanoma cell growth. *International Journal of Photoenergy*; **12**: 231-241.
- Liang, J., Zhu, D., Meng, J., *et al.* (2008). Performance and application of far infrared rays emitted from rare earth mineral composite materials. *Journal of Nanoscience and Nanotechnology*; **8(3)**:1203–1210.
- Masuda, A., Miyata, M., Kihara, T., *et al.* (2004) Repeated sauna therapy reduces urinary 8-epi-prostaglandin F(2alpha). *Japanese Heart Journal*; **45(2)**:297-303.
- Matsushita, K., Masuda, A. and Tei, C. (2008). Efficacy of Waon therapy for fibromyalgia. *Internal Medicine*; **47(16)**:1473-1476.
- Meng, J., Jin, W., Liang, J., *et al.* (2010). Effects of particle size on far infrared emission properties of tourmaline superfine powders. *Journal of Nanoscience and Nanotechnology*; **10(3)**:2083–2087.
- Miller, J. L. (1994). Principles of infrared technology: A practical guide to the state of the art. New York, New York. Kluwer Academic Publishers: 368.
- Oosterveld, F.G., Rasker, J. J, Floors, M., *et al.* (2009) Infrared sauna in patients with rheumatoid arthritis and ankylosing spondylitis: A pilot study showing good tolerance, short-term improvement of pain and stiffness, and a trend towards long-term beneficial effects. *Clinical Rheumatology*; **28(1)**:29–34.
- Ogita, S., Imanaka, M., Matsuo, S., *et al.* (1990). Effects of far-infrared radiation on lactation. *Annals Physiological Anthropology*; **9(2)**:83–91.
- Ozdemir, F. and Kargi, A. (2011). Electromagnetic Waves and Human Health: In *Electromagnetic Waves*, Zhurbenko, V. (Ed.). InTech Publishers: 321.
- Perez-Pinzon, M. A., Stetler, R.A. and Fiskum, G. (2012) Novel mitochondrial targets for neuroprotection. *Journal of Cerebral Blood Flow and Metabolism*; **32(7)**:1362–1376.
- Ravna, A.W., Sylte, I. (2012). Homology modeling of transporter proteins (carriers and ion channels). *Methods in Molecular Biology*; **857**:281-299.
- Sheppard, A.R., Swicord, M.L. and Balzano, Q. (2008). Quantitative evaluations of mechanisms of radiofrequency interactions with biological molecules and processes. *Health Physics*; **95(4)**:365–396.
- Sommer, A. P., Caron, A. and Fecht, H. J. (2008). Tuning nanoscopic water layers on hydrophobic and hydrophilic surfaces with laser light. *Langmuir*; **24(3)**:635–636.
- Sommer, A.P., Zhu, D., Mester, A.R. and Försterling, H.D. (2011) Pulsed laser light forces cancer cells to absorb anticancer drugs – the role of water in nanomedicine. *Artificial Cells Blood Substitute Immobilization Biotechnology*; **39(3)**:169–173.
- Vatansever, F. and Hamblin, M.R. (2012) Far infrared radiation (FIR): Its biological effects and medical applications. *Photonics and Lasers in Medicine*; **1(4)**:195-213.
- Wang, F., Liang, J., Tang, Q. Li, L. and Han, L. (2010). Preparation and far infrared emission properties of natural sepiolite nanofibers. *Journal of Nanoscience and Nanotechnology*; **10(3)**:2017–2022.
- Yamada, Y., Itoh, Y., Aoki, S., *et al.* (2009) Preliminary results of M-VAC chemotherapy combined with mild hyperthermia, a new therapeutic strategy for advanced or metastatic transitional cell carcinoma of the urothelium Cancer. *Chemotherapy Pharmacology*; **64(6)**:1079-1083.
- Yoo, B.H., Park, C.M., Oh, T.J., *et al.* (2002). Investigation of jewelry powders radiating far-infrared rays and the biological effects on human skin. *Journal of Cosmetic Science*; **53(3)**: 175–184.
- Yamashita, K. (2012). The effects of far-infrared(FIR) energy radiation on living body: In *Blood Cell- An Overview of Studies in Hematology* Moschandrou, E.(Ed). InTech Publishers: 360.