

The Biological Effectiveness and Medical Significance of Far Infrared Radiation (FIR)

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ABSTRACT

The electromagnetic waves constitute different wavelengths of light from which Far infrared (FIR) is beneficial for living cells. Extensive studies and trials have been conducted over the last two decades in multidimensional biological domains to identify its unlimited health benefits. FIR radiations improve the microcirculation of the human body, stimulate cell growth, penetrate through skin tissues non-invasively, create intramolecular vibrations create an overall healthy metabolism, which ultimately affects overall improved cardiac and metabolic activity. This phenomenon is used to explore different pathological conditions to identify their significance in the medical field. In this review, we explored the biological effectiveness and the medical significance of Far infrared radiation (FIR) in murine melanoma Cell Growth, Lymphedema, airborne viruses, Cardiac diseases, Wound healing and burns, Autonomic Activities, Hemodialysis, Allergic Rhinitis, Aesthetic medicine, textiles, and other domains such as obesity and gut microbiota.

Keywords: Far infrared radiation (FIR), Infra-red, Electromagnetic waves, Biological effectiveness, Medical significance

Manuscript Received: 14 April 2021

Revised: 29 May 2021

Accepted: 10 June 2021

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INTRODUCTION

The potential of the energy greatly relies on the temperature to emit from a particular material. The sun is the most vital example of radiating radio-magnetic rays with an external temperature of 6,000°C and about 15,000,000°C at the inside. These rays, when entering the atmosphere of earth, lost their radio magnetic potential. In case, an infinitesimal amount of these potential rays can cause a nonreversible DNA damage to the human epithelial surface and even cancer. The received sunlight on earth composed of 6% ultraviolet rays, 52% visible rays, and 42% infrared rays. This sunlight has unlimited potential benefits to the living cells, if use in a right way (Yamashita, 2012).

The wavelength of infrared (IR) electromagnetic radiation is 780 nm and 1000 μm . Based on the wavelengths, IR is categorized into three major bands: Near-Infrared, Mid-Infrared, and Far-Infrared (FIR). The wave length of 50.0–1000.0 μm categorized as FIR (Tsai & Hamblin, 2017; Vatansever & Hamblin, 2012). An extensive literature based on the animal and human trials reported IR as a wound healing, preconditioning the skin, photo prevention, relief body tension/pain, exhaustion of rheumatoid arthritis, positive therapeutic effect on inflammatory diseases such as ankylosing spondylitis, cancer management by potentiating photodynamic therapy, and help to reduce optic, sensory, Autonomic activities, and psychological complaints. FIR is also beneficial to vitalize heart and mesenchymal stem cell functions and as a supportive management approach in aesthetic medicine (Yamashita, 2012; Tsai & Hamblin, 2017; Vatansever & Hamblin, 2012; Barolet et al., 2016; Cristiano, 2019; Yang et al., 2017). FIR Reflecting Textiles and

clothing are other promising approaches to improve the functional abilities of the human body (Basuk, 2018). Recent studies reported additional emerging benefits of FIR, the deployment of FIR costumes in sports for better performance outcomes, and the inactivity of airborne microbial DNA (Bontemps et al., 2021; Li et al., 2020). Anticipation of Coronary heart disease also possible by the responsiveness of endothelial cells using FIR (Tsai et al., 2020).

STATEMENT OF THE PROBLEM

To resolve the FIR-related ambiguities and their health and medical effects, the tissue culture FIR incubator and animal breeding structure was designed. The carbon dioxide incubator certainly the perfect controlled environment example of FIR having $37\pm 0.5^{\circ}\text{C}$ temperature (Yamashita, 2012). The human body is largely composed of water molecules. The main concern related to FIR medical application is its interaction with water molecules. The important considerable features are ionic water interaction, dipole movement, and dielectric features. Another consideration of every living cell is its electromagnetic field. The cell proteins and charged particles are vital to cell components to balance the total cell activity. These charged particles also dependent on water molecules to attribute their dielectric behavior, which eventually responsible for the biological activity of every living cell. To conclude this, water is the most important content between FIR and living cell interaction. There are many peaks of large molecules in the FIR spectrum. There are six vibrating modes of CH_2 compounds or organic compounds, i.e symmetric, antisymmetric stretching, scissoring, rocking, wagging, and twisting (Vatansever & Hamblin, 2012).

Recent scientific experiments and literature find out that the biological activity of FIR is not dependent on cell thermal activities. However, no formal and genuine method yet defined to measure its non-thermal cellular and biological activities which identify the limitations and restrictions of the biological and medical effectiveness of FIR. However, animal trials are ongoing to identify the FIR biological index (FBI) and beneficial irradiation time by using the mitochondrial function of epithelial cells. No conclusive evidence yet identified (Hsu et al., 2019).

Table 1: Over view of the selected studies

S. no	Author(s)	Year	Applications
1	Leung et al.	2012	Murine Melanoma Cell Growth
2	Li et al.	2018	Lymphedema
3	Li et al.	2020	Instability of airborne viruses
4	Beever	2009	Cardiovascular risk factors
5	Tsai et al.	2020	Coronary artery disease
6	Lin et al.	2013	Arteriovenous Fistula
7	Lin et al.	2015	Wound Healing
8	Simmons et al.	2018	Burn wound
9	Yang et al.	2017	Autonomic Activities
10	Su et al.	2009	Hemodialysis
11	Hu et al.	2007	Allergic Rhinitis
12	Chu et al.	2015	Allergic Rhinitis
13	Suwandee et al.	2014	Cosmetics
14	Cristiano	2019	Aesthetic medicine
15	Basuk	2018	Textiles
16	Bontemps et al.	2021	Sports garments

In this comprehensive review we will summarize the key findings of the scientific literature, specifically published in the last decade to explore and implement the new FIR medical applications and their biological effectiveness. An extensive literature search was conducted to find out the development of FIR in biology field and the significance of its medical significance. Table 1 presented the overview of selected studies.

EMERGING FIR MEDICAL APPLICATIONS AND ITS BIOLOGICAL EFFECTIVENESS

Effect of FIR in Chronic Diseases

Lymphedema is a life-threatening pathology characterized by the accumulation of body fluid, particularly in the legs. FIR radiation thermotherapy (FIRT helps tissue fibrosis in Lymphedema patients. A study was conducted in 2015 & 2016 participated by stage II–III lymphedema patients for 20 sessions of FIRT therapy. The study reported a quite satisfactory outcome in improving tissue fibrosis and epithelial elasticity, affecting the overall quality of life (Li et al., 2018). An evaluation was done by using skin elasticity, which improved by $p < 0.05$, ultrasound testing for fibrosis status, and laboratory testing for fluid concentration. The improvement was seen in reducing tension, heftiness, pain, numbness, firmness, and discomfort (Li et al., 2018). Another study reported promising outcomes in Murine

melanoma cells, particularly B16- F10 by using somathermal cFIR. The FIR application reduce the melanoma cells proliferation, intracellular nitric oxide, and heat shock protein by 11.8%,15.7%, and 56.9% after 48hrs of exposure (Leung et al., 2012). Somathermal cFIR strategy represses the B16-F10 proliferation and shuts down the production of nitric oxide and HSP70. Intracellular Reactive oxygen species also produced due to cFIR cell exposure, which leads to cell cycle disturbance and ultimately growth arrest (Li et al., 2018). However, this research domain required further large scale research to find out the standard cFIR strategy for management of chronic diseases.

Instability of airborne viruses

Airborne microorganisms are great threat to human beings and the recent pandemic of SARS-CoV-2 is its classical example. Studies conducted to explore the effect of FIR to control these airborne micro-organisms which are around everywhere to cause life-threatening respiratory infections. Far infrared (FIR) heating fans are the accessible product to warm the closed environments. These FIR heating fans emit electromagnetic radiation between 5.6–1000 μm (Li et al., 2020; Shui et al., 2015). These radiations disturbed the nucleic acids of DNA and RNA viruses (Li et al., 2020). DNA viruses won't significantly damage by FIR radiations. However, significant degradation of RNA viruses was reported as a result of FIR heating fan exposure. Four-hour duration of 400 wattages of FIR heating fans in a 51m³ room area was recommended. Using these Far infrared (FIR) heating fans is a reliable and cheap method to reduce the flow of infectious RNA airborne viruses (Li et al., 2020). Most life-threatening air-borne viruses are RNA viruses including influenza, Severe acute respiratory syndrome (SARS), and SARS, CoV-2, which makes this strategy the most appropriate to adapt (Li et al., 2020; Shui et al., 2015).

Reducing Cardiovascular risk factor

An extensive review was conducted in the last decade to analyze the effect of FIR ranging from 0.75-1000 μm to improve cardiac health. Congestive heart failure (CHF), coronary risk factors, chronic pain, chronic fatigue syndrome were the analyzed pathological conditions. The most adapted method was an infrared sauna that reportedly improves ventricular arrhythmias and endothelial function to reduce the risk of congestive heart failure and improve overall cardiac health (Beever, 2009). The overall response of FIR saunas was very effective for cardiac health based on different randomized control trials. However, these studies did not conclude the recommended exposure time, measurement of basic parameters before and after exposure such as blood pressure, heart rate, etc. Some studies rehydrated the participants before a day of collecting post-treatment parameters, such as hematocrit, glucose, cholesterol, catecholamine, and triglyceride values (Beever, 2009). A recent study further explores this benefit and identify that miR-548aq-3p is the distinctive target for the prediction of heart disease by using Far infrared radiation (Tsai et al., 2020). miR-548aq-3p target not yet identified as any biological role, it was explored that this novel target may enhance the functionality of Endothelial colony-forming cells after FIR radiation. These Endothelial colony-forming cells responsible for the vascular restoration and coronary artery disease (Tsai et al., 2020).

Arteriovenous Fistula and FIR therapy

Arteriovenous Fistula malfunctioning occurs because of multiple genetic, pathological, and mechanical reasons. The development of Arteriovenous Fistula is a major cause of patients with chronic renal disease. A study was conducted by using FIR WS TY101N technology to evaluate the FIR efficiency in chronic renal disease - Arteriovenous Fistula patients. The promising results were reported, and FIR greatly improves the Arteriovenous Fistula in stage IV and V renal disease patients (Lin et al., 2013). Vasodilatation was created due to the thermal reaction of FIR radiation. The FIR radiation was provided up to 2-3cm deep of the skin surface by increasing the temperature to 38°C-39°C. The exposure time of 30-60minutes was recommended to conduct this process, 3 times a week up to 1 year (Lin et al., 2013). The initial therapeutic benefits were on the severity of disorder and rate of embolism and presence of clots (Lin et al., 2013).

Wound Healing and Burns

Wound healing by FIR application is one of the crucial domains of FIR applications. Initially, there was an ambiguity that FIR did not participate in wound healing. Later on, many trials were conducted to find out that after exposure to FIR radiations the blood flow of the exposed wound area was increased. Many scientific researches were conducted on animal models initially to affirm the research concept and identified the gene expression of TGF-b1 at the wound site for healing. These studies find out that FIR radiation promotes the biological activities of the wound area including blood circulation, proliferation of fibroblast, collagen formation, and TGF-b1production (Lin & Li, 2017; Toyokawa et al., 2003; Yu et al., 2006).

The phenomenon further explored for burn wounds, and studies conducted on extreme superficial burns to identify the decision of skin graft. Skin grafting is the most suggested management in most extreme burn wounds. However, the clinical examination is deficient to conclude the management decision. The FIR radiations helped in burn wounds to identify the viability of the burn site, which is quite difficult by physical examination. FIR technique is simple to explore the true diagnosis in burn wound and decision of grafting (Simmons et al., 2018). FIR camera - Therm-App®

camera use to execute this phenomenon by taking images of burn site up to 2 minutes in every 5 seconds. Total of 24 images collected in 2 minutes. After grafting, the same process applied to identify the progress of burn wounds in deep cells. This FIR technique reportedly the most precise technique to identify the true status of burn wounds, its grafting decision, and progress after grafting (Simmons et al., 2018).

Far-Infrared and Acupuncture therapy to improve Autonomic Activities and Stroke

Having multiple benefits of FIR in wound healing, and improvement in cardiac health by engaging fibroblast and increase blood circulation, its role in autonomic activities were explored in combination with acupuncture, which is the traditional management approach for many disorders. The combined management strategy of using acupuncture and FIR radiation was reportedly highly beneficial in cardiac disorders, metabolism, hypertension, and stroke (Yang et al., 2017; Hu & Li, 2007).

Animals and human trials have been conducted to find out the FIR application in brain injury and stroke patients. However, these studies were inconsistent in the last decade but yet have a promising future. Transcranial near-infrared light therapy (NILT) was the adapted application to cure brain injury in stroke patients. NILT creates neuro regenerative modification by enhancing adenosine triphosphate (ATP) release, DNA replication, gene response, promote expression of growth factors, cell proliferation, and synaptogenesis (Hu & Li, 2007; Henderson, 2016).

Allergic Rhinitis

Allergic rhinitis (AR) is a heterogeneous chronic respiratory disorder; ranked sixth among the most reported chronic complaints globally and greatly affects patient's wellbeing and quality of life. The management of AR is quite complex which greatly affects patient's daily life due to additional precautions and medications. The identification of allergen, allergen prevention, pharmacological medicines, and immunotherapeutic are the routine management requirements of AR. FIR radiations by using WS TY101 FIR emitter to the nasal area of the affected patient were significantly helpful. The outcome depends upon the illness severity by improving irritation of eyes and nose, sneezing, and running nose (Su et al., 2009; Cho et al., 2015). This treatment is significantly helpful to a large population group, especially in seasonal allergens (Su et al., 2009; Cho et al., 2015).

Cosmetics and Aesthetic medicine and FIR application

Having unlimited health benefits of FIR on human cells, cosmetics, and aesthetic medicine also took advantage of these radiations to provide a healthy, reliable, and affordable beauty solution. Sauna blankets one of the most productive aesthetic approaches of FIR. FIR Sauna therapy is quiet promising for chronic pain relief, chronic fatigue syndrome, and weight loss due to neurohormonal cell response (Biro et al., 2003; Masuda et al., 2005a; Masuda et al., 2005b). There are unlimited FIR cosmetic products are available; such as FIR blankets, soft lasers, FIR lamps, FIR caps, and FIR helmets (Cristiano, 2019; Suwandee & Yupapin, 2014). All these tools had medicinal benefits on human cells, both localized and systemic depending upon the tool used. Removal of fat promotes hair growth and treating alopecia are some of its aesthetic benefits (Cristiano, 2019). The aesthetic FIR devices are also available in markets for home use such as FIR hair brushes to prevent hair loss and hair shining. FIR lamps and FIR pens are also easily available. FIR pens used for pain relief on certain points such as the neck or back. There are unlimited beauty products are available which used FIR radiations, to make their product more beneficial for humans (Cristiano, 2019; Suwandee & Yupapin, 2014).

Effect of Infrared-emitting textiles and potential of FIR garments in sports

FIR domain is greatly explored by technology advancement. The technology of nanoparticles used to impregnate textile fibers with FIR radiations. These garments used to obtain numerous health advantages and well-being of humans (Basuk, 2018). This textile development use radiations of 700nm to 1mm. The fabrics designed by using FIR emitting potential, designed by adding IR potent trace elements, metals, and ceramics. The main characteristics to choose a suitable component for FIR fiber designing are high heat retention and the ability to absorb and reserve heat. The reverse mechanism applied in a cold environment, the heat generated by human cells preserve in these fiber components to prevent heat loss and make you feel warm (Basuk, 2018). This heat shifting is the basic mechanism of FIR textiles. Based on this, FIR textiles designate into different groups such as:

- Passive textiles to regulate the temperature of the human body, either way, warm or cold,
- Active warming/cooling textiles to add additional warm or cool input.

Responsive textiles for personal management of thermal indicators such as temperature, moisture, and pH of the human body (Peng & Cui, 2020; Farooq & Peng, 2021). Almost all clothing forms of FIR radiating fibers are available, with the specification of clothing insulation measure. This clothing insulation information based on the heat retention capacity and controls the thermal balance of the human body (Basuk, 2018). These FIR garments demand by elderly people and urban residents (Basuk, 2018).

Manufacturing of sports, garments is an additional domain in sports textiles for performance optimization and better outcome of the sports person. The athletes and gymnasts, because of countless related benefits, had widely accepted compression garments but is it a reality or fad, is still an exploring doubt (Beever, 2009). An extensive review recently published by Bontemps et al. (2021) to clarify the related uncertainty (Beever, 2009). The study concludes that these sports garments generate a better productivity outcome by controlling the human body's hemodynamic and thermoregulation activities (Beever, 2009). These sports garments, depending upon the fiber nature, control blood flow, body temperature, oxygen intake, Cardiac activity, serum lactate, Increase Creatinine kinase, body posture, sleep activity, etc. (Beever, 2009). These garments have an immiscible category in health improvement; still, there is a lot more to explore. Physiotherapy is a medical subcategory responsible for the mobility of human muscles and patients' better well-being (Putowski et al., 2016). There are many FIR apparatus for better patient outcome, used in physiotherapy such as lamps, Electrotherapy, Magnetic therapy, Phototherapy, etc. FIR garments are yet to explore in Physiotherapy (Beever, 2009).

OTHER BIOLOGICAL BENEFITS

FIR radiations have multi-dimensional potential in health care and medical. Animal trials have been conducted to explore its benefits in cell metabolism, obesity, and weight loss. These animal trials were quite promising to develop a management strategy of weight loss by using FIR radiations. FIR radiations reduce appetitive by modifying gene expression of TRPV3-POMC (Hu et al., 2011). Another animal study finds out the modification of GLUT-4 gene expression in response to FIR radiations to control obesity (Kokura et al., 2007). These gene modifications were happened due to the hypothermia caused by FIR radiations (Hu et al., 2011; Kokura et al., 2007). Another recent study on the animal models investigated the phenomenon of FIR impact on gut microbes. The findings suggested the gastrointestinal modulation by activating the Host's G-protein-coupled receptors (GPCR) (Khan et al., 2020).

CONCLUSION

FIR has unlimited health benefits and impact on the human body among all other electromagnetic waves, which are yet to explore. In this review, we explored the most recent scientific literature reported the significant medical applications of FIR radiations and their promising outcome. However, there is a great need to investigate its benefits in managing chronic diseases, and life-threatening medical threats like SARS-CoV-2.

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