Neurobiological Mechanisms and Perspectives on Far-Infrared Emitting Ceramic Materials for Pain Relief

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Pain is an important, evolutionarily conserved physiological phenomenon that is necessary for survival. At the same time, pain is one of the most frequent symptoms of a variety of pathological disorders and represents a major clinical challenge [1]. Although the acute pain that accompanies minor tissue injury is protective, chronic pain typically persists long after injuries have subsided [2]. Chronic pain is characterized by its long-term nature and abnormal sensitivity to thermal and mechanical stimuli and can take the form of hyperalgesia, an excessive reaction to a normally painful stimulus, or allodynia, a painful response to normally innocuous stimuli [3]. Several types of physical therapy are used in the management of pain [4]. These treatment modalities can be categorized as electrotherapy modalities, acupuncture, thermal modalities, exercise, manual therapies or phototherapy [4]. In the last few years the biomedical research area is going towards materials science aiming applications of bioceramic materials to health care, the so-called Far-Infrared Emitting Ceramic Materials (cFIR). A recent promising development of cFIR is related to the field of pain.

Bioceramics are refractory, inorganic, nonmetallic polycrystalline compounds that due to their inertness in aqueous conditions are highly biocompatible and thus have been extensively used in implants [5], but in the last few decades bioceramic materials have been studied for yet another property: their ability to reflect/emit far-infrared. cFIR when reduced to powdered format can be incorporated in an array of products such as fabrics, all sorts of polymers and inks to create products that produces FIR which has been shown to present a gamut of health benefits, including analgesic, anti-inflammatory and anti oxidative activities (for a review see Vatasever and Hamblin [6]).

As direct result of the advances in cFIR research, in the last decade many companies started to implement cFIR medical items, such as belts, braces and patches, e.g., Thermocold in Australia, Neomed in Korea, Shen Wan in China and BioPower in the United States and Brazil, to name but a few. These products are now being used by physical therapists and other health care professionals as adjuvant to more traditional approaches, mainly due to the fact that patients can extend the treatment effect, by simply wearing the products at home.

To understand the health benefits of cFIR derived products, it is important to understand what FIR is as well as its benefits: FIR is a region of the infrared spectrum of electromagnetic radiation from 3 to 100 μm (International Commission on Illumination classification of IR radiation) which has the ability to penetrate up to 1.5 inches (almost 4 cm) beneath the skin [6]. Particularly in the range of 8 to 12 μm, FIR has been shown to present many beneficial biological effects [7]. FIR emitted by saunas and other FIR generators powered by electricity uses irradiances in the range of tens of mW/cm² and is perceived as heat by the thermoreceptors in human skin; whereas FIR emitted by cFIRs, has such low irradiance (0.1-5 mW/cm²) that is not enough to heat the tissue [8]. Different from FIR devices powered by electricity, the source of energy that powers the emissions from the cFIR comes from the human body, which is normally at a higher temperature than the environment. In this process body energy is transferred to the ceramic materials, which reflect/emit FIR back to the body at varying levels depending on its molecular composition.

The underlying mechanisms of the interaction of low irradiance FIR (such as the one emitted by cFIR) with living cells is not fully understood; it has been demonstrated that low irradiance FIR absorption causes the collapse of water clusters, and the energy transfer may be converted into molecular vibrations [9]. Based on this premise, Vatasever and Hamblin [6] suggest that if the relatively small amount of vibrational energy delivered non-heating FIR (photons with quantum energy levels of 12.4 meV-1.7 eV) could act upon the so-called nanostructured water layers that build up on hydrophobic surfaces such as cellular membranes [10] it could then trigger small perturbations in the membrane structure that could ultimately affect ion channel permeability. Particularly in mitochondrial membranes this process could give rise to a brief burst of ATP production, increased oxygen consumption and formation of ROS [11]. As an outcome, signaling pathways activated by ATP, NO, and ROS would lead to activation of transcription factors (e.g., NF-κB) [12] and long-term effects (analgiesic and anti-inflammatory), in a process similar to that obtained with Low Level Light Therapy (LLLT) [13,14].

Although this hypothesis has to be confirmed by hard data, in recent years many studies support the analgesic effect of cFIR, e.g., preclinical (in vitro and in vivo models) demonstrated that cFIR treatment (1) produced significant inhibitory effects on both prostaglandin E2 (PGE2) and cyclooxynase-2 (COX-2) under LPS stimulation in vitro [15]; (2) induced anti-arthritic and anti-inflammatory effects (PGE2 inhibition) in vitro and in a rabbit model of rheumatic arthritis [16]. These data suggest a possible anti-inflammatory and pain relief mechanism for cFIR. Moreover, clinical trials demonstrate that cFIR in fabrics (1) reduced pain, intolerance to cold and periodic movements in post-polio syndrome patients [17]; (2) reduced pain in patients with arthritis and peripheral vascular disease (Ko and Berbrayer [18]); and (3) increased cutaneous perfusion and induce analgesia in patients with Complex pain syndrome type I [19]. In addition, a cFIR plaster reduced pain in the therapeutic management of knee osteoarthritis in a single blinded, randomised clinical trial [20]; cFIR “Thermoflow” Gloves reduced pain, increased grip strength and hand dexterity in patients with Raynaud’s Syndrome [18], the use of cFIR belt reduced pain and discomfort in patients with primary dysmenorrhea in more...
than one study [21-23]; and lastly, the short term use of a cFIR neck device partially reduced muscle stiffness suggesting and application in the management pain, in a trial involving 48 patients with chronic myofascial neck pain [24].

Even though some progress has been made, the precise neurobiological mechanisms mediating the therapeutic effects of cFIR are still far from being completely understood, let alone the possible interactions with the other therapeutic modalities. In spite the need for additional, more in-depth research, the ever-growing number of studies on the subject state to the fact that this form of therapy is here to stay as a non-invasive, affordable, and more importantly, highly practical complement to a physical therapy treatment and other health care modalities or simply as a means to help maintain the wearer’s well-being.

References