The Mechanism and Research Application of Far-infrared Textiles Relieving Sports Fatigue

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Abstract: Aiming at the causes of sports fatigue, one of the main means to alleviate sports fatigue is to reduce lactic acid in the body. Combined with the development and application of far-infrared fibers this year, using its physical properties and biological effects on the human body, the far-infrared energy reaches deep tissues and organs, causing the body to produce a warming effect, dilating blood vessels, accelerating blood flow, and blood Stagnation is reduced, which can reduce lactic acid in the body during exercise and achieve the purpose of alleviating fatigue. At present, far-infrared has been developed and applied in some fields. The research and deeper application of far-infrared in the fields of medicine and kinematics are the focus of future development.

1. Introduction
Fatigue during exercise not only affects exercise performance, but can also cause serious sports injuries. At present, many experts and scholars at home and abroad have carried out research on methods to relieve sports fatigue, and the research content is mainly concentrated on physical methods and drug therapy. Far-infrared textiles have health care, thermal insulation and antibacterial properties. Their physical properties and biological effects on the human body have an impact on sports fatigue, providing a new research idea for alleviating sports fatigue.

2. Mechanism of far-infrared relieving sports fatigue

2.1. Sports fatigue
From the perspective of the development of sports science, the study of sports fatigue began in the 1970s and 1980s. In 1982, the accurate definition of sports fatigue was proposed at the 5th International Sports Biochemistry Conference on sports fatigue. The definition is: "Exercise fatigue, that is, the body's physiological process cannot maintain its function at a certain level and/or cannot maintain a predetermined exercise intensity."¹

At present, lactic acid is one of the most studied fatigue-causing substances. When the human body exercises vigorously, it will consume a large amount of ATP and CP, and the muscle glycogen and glucose stored in the muscle will be decomposed into lactic acid under anaerobic conditions to participate in energy supply. With the increase of exercise time, muscle glycogen is consumed in large amounts, and the accumulation of lactic acid in the muscles increases the osmotic pressure and water content of the muscles, causing the muscles to become stiff, and the elasticity and stretchability are greatly reduced, which is an important cause of sports fatigue. In addition, due to the penetration of...
water into the muscle fibers, the muscles are inflated, and the painful nerves in the muscles are physically compressed, and muscle soreness is generated [2].

2.2. Far-infrared textiles
Far-infrared textile refers to the effective fusion of far-infrared ceramics and textiles, which can absorb electromagnetic waves emitted by the human body or the environment within a certain wavelength range, and radiate far-infrared rays with a wavelength of 2.5-30μm, which can promote blood circulation and regulate metabolism functional textiles.

Infrared is an electromagnetic wave between visible light and microwave. Its wavelength range is 0.76-1000 μm. It is scientifically divided into three bands: near infrared band, mid-infrared band, and far infrared band, as shown in Figure 1[3]. In the field of health care, the mid-infrared band is included in the far-infrared band. The unique physical properties of far-infrared rays are absorbed by the human body after acting on the human body, and will produce a series of biological effects: (1) Warm effect; (2) Resonance effect, activate water molecules; (3) Improve human microcirculation function and enhance human metabolism; (4) Activate macromolecules in the body, lower blood fat, lower cholesterol; (5) Improve immune function.

![Figure 1. The electromagnetic wave and wavelength of sunlight](image)

According to Kirchhoff's radiation law, all objects containing far-infrared rays can radiate far-infrared rays or absorb far-infrared rays. The human body can both radiate far-infrared rays and absorb far-infrared radiation. Tests show that the human body's infrared spectrum has two absorption peaks at room temperature: a secondary absorption peak with a spectrum width of 2.5 to 4 μm and a main absorption peak with a width of 5.6 to 10 μm[4]. According to Wien's displacement law:

\[ \lambda_m T = 2897.6 \]

\( \lambda_m \) is the main wavelength, the unit is μm; T is the absolute temperature; when the surface temperature of the human body is 36.5°C, the dominant wavelength of the far-infrared radiation it absorbs is about 9.36μm, which is exactly within the main absorption peak interval of the human body and is at a peak of 9-10μm[5]. The wavelength of the far-infrared rays generated in far-infrared textiles is 8-15μm, which matches the wavelength of radiation absorbed by the human body. Because 60% to 70% of the human body is water, the absorption of far-infrared radiation by the human body is similar to that of water. The specific vibration frequency and the number of gyration cycles possessed by the human tissue are stretched with the O-H and C-H bonds in the human tissue, C-C, C=C, C-O, C=O, C-H and O-H bond bending match. According to the matched absorption theory, when the wavelength of the far-infrared radiation corresponds to the absorption wavelength of the radiated object, the object molecules resonate and absorb. That is to say, the molecular vibration frequency of the far-infrared fiber has the same vibration frequency as the water molecules in human tissues. When the two meet, the energy absorbed by the water molecules stimulates another vibration, which eventually produces the result of resonance resonance. It caused the skin to heat up, prompting the temperature of the tissue to rise, expanding the superficial tissue and capillaries, and forming the effect of health care therapy.
2.3. The mechanism of far-infrared textiles alleviating sports fatigue
Lactic acid accumulation is the cause of sports fatigue. Therefore, the essence of eliminating fatigue is to remove metabolic intermediates such as lactic acid, so that the body can recover as soon as possible.

Far-infrared rays have the characteristics of radiation, penetration, resonance and absorption. When used for local irradiation, its radiant heat can penetrate into the skin barrier and absorb the tissue to produce a warming effect. On the one hand, the warming effect increases the skin temperature, stimulates the intradermal heat sensor, and relaxes the smooth muscles of the blood vessels through thalamus reflection. Blood vessels dilate and blood flow accelerates. On the other hand, it causes blood vessels to release active substances, reduce blood vessel tension, dilate small arteries, capillary arteries, and capillary veins, causing accelerated blood flow and speeding up human circulation. The warming effect improves local blood circulation, accelerates blood flow, reduces blood stasis, and reduces the amount of lactic acid accumulation, thereby effectively improving the structure and function of microcirculation, promoting the absorption and dissipation of exudate, reducing inter-organic tension, and reducing fatigue. And pain, and can strengthen local tissue nutrition and promote tissue healing. In addition, the heat absorbed by the skin passes through the blood circulation and medium, so that the heat energy reaches the body tissues, promotes human blood circulation and metabolism, and has the functions of eliminating fatigue, restoring physical strength and relieving pain. Figure 2 is a schematic diagram of the human body affected by far-infrared fibers.

3. Research status of far-infrared textiles to relieve sports fatigue
In the 1980s, Japan set off a wave of research on far-infrared, and achieved certain results in far-infrared textiles. Russia, South Korea and other countries also followed closely and began to study far-infrared. By the beginning of the 21st century, foreign scholars, especially Brazilian scholars, had reached a climax in the research of far-infrared in medicine. Hausswirth C et al. tested the effect of far-infrared (FIR) on muscle recovery and found that it takes 24 hours to restore maximum muscle strength and sensation using FIR therapy. Mero A et al. found through research that the far-infrared sauna can well promote the recovery of the neuromuscular system. Loturco I et al. found that far-infrared clothing can relieve football players' perception of delayed muscle soreness after strenuous exercise. Salm D C et al. studied the therapeutic effects of water sports and far-infrared (FIR) on patients with fibromyalgia, and found that both groups of treatments can reduce pain, lower body temperature, improve quality of life and lower serum. Nunes R F H et al. investigated the neuromuscular, biochemical and sensory markings of football players wearing far-infrared ceramic pants during nighttime sleep, and found that daily use of cFIR clothing can promote rehabilitation, especially on the sensory markings at the beginning of intensive training.

China began to study far-infrared in the 1990s. With the deeper research on far-infrared, people began to apply it to medicine and kinematics. In 2001, Li Hongjing et al. applied far-infrared ceramics to the fractures of rabbits, and explored their effects on the healing of rabbits after fractures. It was found that the addition of far-infrared ceramics to polymer bandages for fracture fixation has both external fixation and the acceleration effect of accelerated fracture healing provides a new treatment method for fracture healing. Fu Xudong applied far-infrared electrothermal magnetic combination Chinese medicine in
the treatment of sports fatigue and injuries in 2007, and found that the combination of physical therapy and drug therapy can better relieve sports fatigue. In 2011, Leung Ting-Kai et al.\cite{14} studied whether far-infrared radiation can improve exercise performance at room temperature. Through the experiment of CFIR irradiation on mouse myoblasts, it was found that cFIR is enhanced under oxidative stress myoblasts and delay the fatigue caused by muscle contraction. In 2014, Lai Chien-Hung et al.\cite{15} studied the effect of far-infrared radiation on myofascial neck pain and found that patients with chronic myofascial neck pain had obvious stiffness of the upper trapezius muscle after 1 week of treatment decline. It was therefore concluded that short-term treatment with the cFIR neck device can reduce muscle stiffness. He Weijian\cite{16} is committed to studying the effects of far-infrared on skeletal muscles and muscles. In 2020, he studied the changes of three physical properties of muscle physics after the intervention of far-infrared ceramic microbeads. He concluded that far-infrared ceramic microbeads can increase muscle stretchability and elasticity, reduce muscle hardness, and promote the recovery of injured muscles. At the same time, this part of the muscles is more coordinated in the process of stretching and relaxing when acting as antagonistic muscles during exercise, improving the fluency and stability of the exercise.

Modern medicine believes that muscle tension and muscle pain are not sports injuries, but a manifestation of skeletal muscle fatigue. Scholars from various countries apply far-infrared to the treatment of sports fatigue based on the physical characteristics of far-infrared and the biological effects on human body.

Li Xuan\cite{17} used time-frequency joint analysis method, combined with time-domain index and frequency-domain index to evaluate muscle fatigue, and divided 4 states of muscles in exercise into 4 levels. Level is inversely proportional to muscle status. Through the functional testing of far-infrared fabric and nylon fabric cycling pants, it was found that far-infrared fabric cycling pants can relieve sports fatigue. The content of far-infrared yarn has a significant effect on improving muscle fatigue, and the higher the content of far-infrared yarn, the more Big. During exercise, the far-infrared cycling pants will restore muscle fatigue in 14-20 minutes and 26-36 minutes.

Lin Yungsheng et al.\cite{18} evaluated the effect of the far-infrared emission collar (FIRC) on the treatment of neck diseases by comparing the collar of a textile fabric containing 10 wt% FIR ceramic (FIRC) with a fake collar without FIR ceramic inside. Power analysis of the sample size obtained, found that FIRC can improve neck disease by reducing neck muscle hardness, can improve neck disease by increasing skin temperature and promoting blood circulation, as well as relieve pain, reduce fatigue, improve depression And the effect of reducing anxiety.

In addition, the far infrared fiber has a porous surface due to the core structure, as shown in Figure 3\cite{6}, increases the surface area of the fiber, and significantly improves the surface activity, surface adsorption, diffusion and other characteristics, so that the product has functions such as sterilization, sweat absorption, and deodorization.

![Figure 3. Core structure of fiber](image)

**4. Conclusion**

Through the analysis of the mechanism of sports fatigue, it is found that the accumulation of lactic acid will cause sports fatigue. The far-infrared textiles produce radiation to the human body, which causes the human body to have a warming effect and a resonance effect, causing the skin temperature to rise, dilating the superficial tissues and capillaries, accelerating blood circulation, reducing the amount of lactic acid accumulation, and can effectively alleviate sports fatigue. At present, experts and scholars in many fields are studying sports fatigue from various aspects and exploring ways to alleviate sports fatigue. The research mainly focuses on the methods of warming the body, massage and drug treatment,
and has achieved certain research results. Combined with the development trend of China's sports and fitness industry in the next few years, while comparing the existing ordinary fabric sportswear on the market, the characteristics of far-infrared textiles to relieve sports fatigue have broad market prospects, and also provide new research for alleviating sports fatigue. The direction allows people to study sports fatigue in more depth from different fields.

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