Antioxidative Effect of Far-Infrared Radiation in Human

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***Abstract*-The antioxidative effect of far-infrared radiation (FIR) in human was evaluated by half maximal inhibitory concentration of blood against superoxide anions. All samples ranging from 18 to 30 years old were grouped into sympathetic, parasympathetic, sympathetic plus parasympathetic and the control group. The ability of antioxidation of blood from the subjects was measured with an ultraweak chemiluminescence analyzer. According to the results, the level of superoxide anions was decreased in sympathetic, parasympathetic, and sympathetic plus parasympathetic group, while that in the control group was increased. This suggested that the FIR radiation performed a significantly antioxidative effect by defending human from oxidative damage of superoxide anions in blood. This may probably be achieved by increasing SOD concentration and/or increasing heart rate variability.**

Keywords- Far-Infrared Radiation; Antioxidative Effect; Ultraweak Chemiluminescence Analyzer; Autonomic Nervous System; Superoxide Anions

I. INTRODUCTION

Infrared radiation is non-ionizing radiation emitted when a molecule de-excites from a higher vibrational or rotational quantum level, which physically expresses as heat [1-3]. In the infrared spectrum, the "growth rays" [4, 5] ranging of 4-14 μm belongs to far-infrared (FIR) spectrum, which is named ascribed to its many beneficial effects represented on organisms [6-9]. For thousands of years, FIR radiation has commonly been used in Chinese medicine to cure diseases by means of moxibustion [10, 11]. Moreover, FIR can also be expressed from qigong practicers, which has long been used to enhance health as well as to heal sickness in Chinese. Many biomedical materials serving growth rays, so called FIR materials, have recently been developed and manufactured for healthcare and clinical applications [12-16]. The emitted heat and radiation from the FIR materials can increase blood circulation, facilitate cell growth [6, 17], and tissue regeneration [18, 19], as well as inhibition of tumor growth [20, 21] and anti-depression [21, 22]. Sleep modulatory effect was also observed in rat under FIR irradiation [6]. On the other hand, positive effects of FIR were found helpful to several chronic diseases, such as joint pain, stiffness, knee osteoarthritis [23, 24], inflammation [25], limitation of muscle extension [26] and cancer [8]. Among the chronic diseases, many arise from damages of superoxide radicals, such as hyper pressure, Parkinson's disease [27], arterial disease [28], hepatitis [29, 30] and others [30, 31]. In this research, we investigated the variation of the concentration of superoxide anions in blood of the recruited subjects treated by different arrangements of FIR hot compress to evaluate the antioxidative effect of FIR in human.

II. MATERIALS AND METHODS

A. Study Population and Testing Environment

Forty-six students aged 18-30 years old were recruited from a university located in Chiayi County of Taiwan (R.O.C.) in this study, which was reviewed and approved by the institutional review board of Dalin Tzu Chi General Hospital in Taiwan (i.e., the approved informed consent was obtained). Written informed consents were returned from all subjects before carrying out the test. None of the recruited subjects possessed a family history of heart, inflammation symptoms or chronic diseases.

By stratified and random sampling with a computer, the volunteers were grouped into four experimental groups, including the sympathetic group (irradiated by FIR on thoracic lumbar vertebra; abbreviated as T; Fig. 1(A)), the parasympathetic group (irradiated by FIR on brain system and sacrum; abbreviated as P; Fig. 1(B)), as well as the sympathetic plus parasympathetic group (treated by FIR on brain system, thoracic lumbar vertebra, and sacrum; abbreviated as W; Fig. 1(C)). The control group was treated the same way as the experimental groups but without FIR irradiation to minimized placebo effect. It was confirmed that neither drug nor coffee-containing food was taken by the volunteers before the test. Volunteer that stayed up late at the night before the testing day was also screened out. The testing environment was quiet, comfortable, and well controlled at 20-

25°C, 40-60% relative humidity and consistent lighting while performing the tests. Only one subject was evaluated at a time during the test.

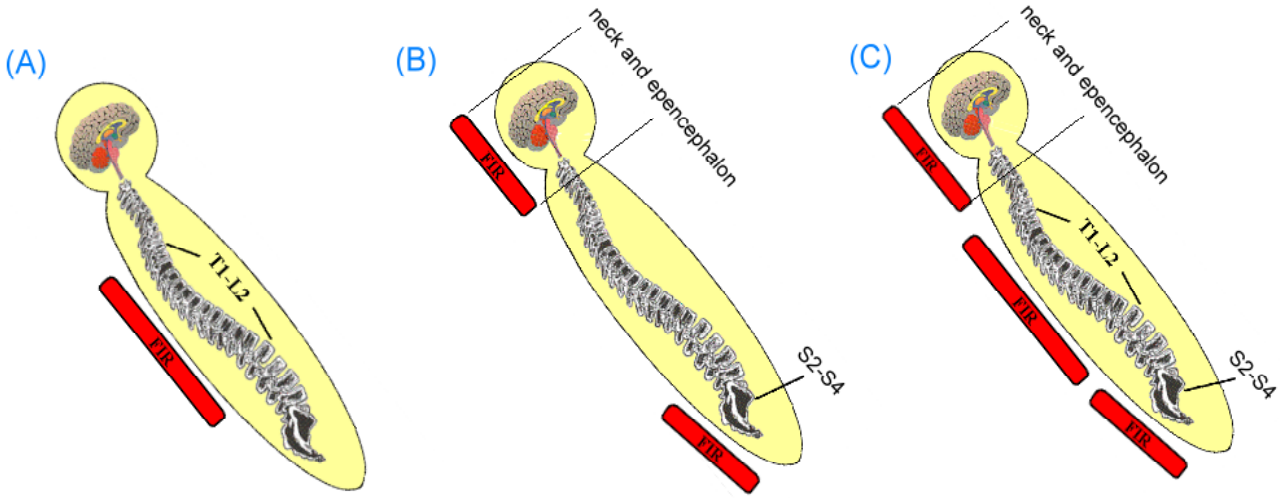

Fig. 1 Arrangements for the experimental groups: (A) the sympathetic group, (B) the parasympathetic group and (C) the sympathetic plus parasympathetic group

B. Equipment for FIR Generation

The FIR equipment obtained from Solano Semiconductor Technology Co., LTD. (R.O.C.) was manufactured as a compress pad with a dimension of 40 cm×28 cm×3 cm and the whole compress surface was embedded with ceramic FIR materials (emissivity=0.85). FIR emission was triggered by a 24 V power supply. Hot compress was implemented at different regions of the spine in different groups: T1-L2 for the sympathetic group; neck and epencephalon for the parasympathetic group; whole spine for the sympathetic plus parasympathetic group (Fig. 1). For the control group, whole spine was contacted to the compress but the power supply was turned off.

C. Sample Preparation and Analysis for Superoxide Anions in Blood

With the availability of an ultraweak chemiluminescence analyzer (BJL-1-IC; Jye Horn Co., Taiwan), the suppression of superoxide anions by the blood samples is possible to be monitored. Before FIR treatment, 2-3 mL peripheral blood was taken from each subject. Except for the control, the treatment of FIR was performed for 40 minutes following a stabilization period of 5-10 minutes. Another 2-3 mL of blood was sampled from the subject at the end of the test. All blood samples were kept at 37°C in the dark and analyzed within 24 hours after collected. An aliquot of 0.5-mL blood sample was pipetted into a glass tube and vortexed to mix. The half maximal inhibitory concentration (IC_{50}) of the total blood against superoxide anions was determined from the change of chemiluminescence intensity. Being corrected for background, the obtained chemiluminescence intensity was represented in terms of average counts per minute.

D. Statistical Analysis

The distributions of characteristics among the testing groups were expressed as percentages for categorical variables and means for continuous variables. The association of categorical data was estimated by chi-square test. The paired t test was used to analyze the difference of concentration of superoxide anions among the groups. The results of each group were compared by a repeated measurement analysis of variances statistic method followed by the Schaffer test for post hoc analysis of significance. A P value <0.05 was considered statistically significant. SPSS version 12.0 was used for statistical analysis in this research.

III. RESULTS AND DISCUSSION

Descriptive variables including gender and age are listed in Table 1. No significant difference among testing groups was observed from the distribution of demographic characteristics analyzed by chi-squared or one-way ANOVA. The concentration of superoxide anions in blood was previously indicated being influenced by age [26, 33-35]. Therefore, the subjects over 30 years old were excluded from the test to avoid the effect of age. Moreover, to evaluate the significance of decreased level among these groups, a decrease percentage of superoxide-anion level for the FIR-exposure groups was determined, which exhibited statistical significance as compared to the control group (Table 2). These results in this study reveal that FIR treatment can effectively reduce the generation of superoxide anions in blood. The changes of chemiluminescence intensity of the experimental groups before and after FIR irradiation was presented in Fig. 2. After FIR treatment as indicated by the result, the chemiluminescence intensity of the control group was increased, while that of the T, P, and W groups was decreased. This indicated that the concentration of superoxide anions in blood of the groups treated by FIR irradiation was eliminated.

TABLE I DESCRIPTIVE STATISTICS OF THE POPULATION (N=46)

Variable		Group				P-value
		Control	T	P	W	
Number (%)		11 (24)	11 (24)	12 (26)	12 (26)	
Gender (%)	Male	6 (27)	5(23)	6(27)	5 (23)	0.93[a]
	Female	5 (21)	6 (25)	6 (25)	7 (29)	
Age (yr)		20.7(2.4)	20.9(2.0)	21.7(1.8)	20.4(2.1)	0.51[b]

[a] chi-squared test
[b] one-way ANOVA
The abbreviation for Groups T, P and W respectively denotes the sympathetic, parasympathetic and sympathetic plus parasympathetic treatment group.

TABLE II DIFFERENCE (AFTER MINUS BEFORE) OF SUPEROXIDE ANIONS BETWEEN BEFORE AND AFTER FIR TREATMENT IN EACH GROUP

Group	Difference Mean(SD)	P-value[a]
Control	18.7±3.74	0.014
T	-17.2±3.58[b]	0.028
P	-15.2±3.98[b]	0.079
W	-17.3±2.61[b]	0.007

[a] pair t test
[b] The group reached statistical significance in comparison with the control group ($P < 0.05$) by repeated analysis of variances method. The abbreviation for group T, P and W denotes the sympathetic, parasympathetic and sympathetic plus parasympathetic treatment group, respectively. The results were obtained from independently triplicate experiments.

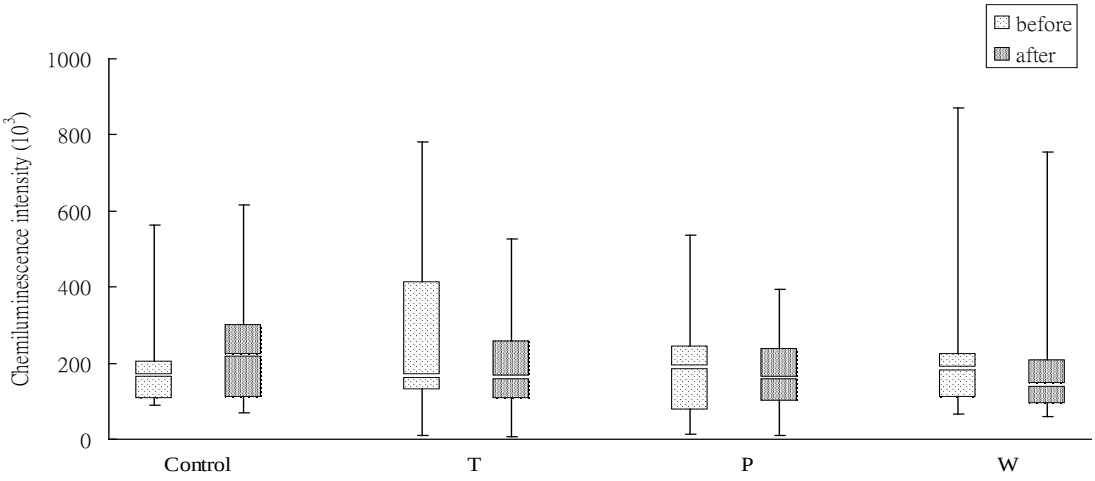

Fig. 2 Variation for concentration of superoxide anions by means of chemiluminescence intensity before and after FIR treatment

The abbreviation of T, P and W denotes the sympathetic, parasympathetic and sympathetic plus parasympathetic group, respectively. The results were obtained from independently triplicate experiments. Data are represented as box-and-whisker plot. The data are represented as box-and-whisker plot, which illustrate the smallest observation, lower quartile, median, upper quartile, and largest observation.

Superoxide anions are deleterious byproducts in mitochondrial respiration in organisms [32], which can poison energy metabolism and release potentially toxic iron by inactivating aconitase even at subnanomolar concentrations [36]. When microorganisms invades, the superoxide anions can also be released by immune system to destroy the invading pathogens (e.g., myriads of superoxide anions are produced by NADPH oxidase in phagocytes) [37, 38-40, 41-43] and causing inflammation symptoms [44]. From Table 2, all the experimental groups treated with FIR represented apparent antioxidative effect on decreasing the generation of superoxide anions, while an increased level of superoxide anions was observed in the control group. In this study, since none of the subjects had inflammation symptoms, the generation of superoxide anions should mainly be ascribed to mitochondrial respiration, and the variation of superoxide concentration could possibly be attributed to increase of superoxide dismutase (SOD), which is responsible for the reduction of superoxide anions in human [45-47]. Thermal as well as non-thermal effects (e.g., increase NO • concentration) of FIR have been proved able to cause vasodilatation and enhance blood circulation [48, 49] may increase metabolism of superoxide anions. According to previous researches [50, 51, 52], the simulation of FIR has been proved to be effective on increasing the production of SOD [27, 53]. In addition, the observed phenomena may also be ascribed to the regulation of autonomic nervous system since the generated heat from FIR irradiation has also been verified able to affect the autonomic nervous system and increase heart rate variability to

eliminate superoxide anions [29, 54-56]. Moreover, we found that all of the hot-compress arrangements (i.e., different spine region of FIR irradiation in this study) exhibited positive effect on the elimination of superoxide anions. However, FIR irradiation on T1-L2 region (the sympathetic group) and whole spine (the sympathetic plus parasympathetic group) revealed better results. As the population lifetime prolongs worldwide, chronic diseases have become an important public health issue. From several studies, chronic diseases have been found arising from damage of superoxide anions [27-31, 57-59]. In this study, we propose that FIR treatment at the spine is beneficial for human in prevention from oxidative damage of superoxide anions.

Therefore, the treatments of this study may provide an alternative strategy to prevent chronic diseases resulting from damage of superoxide anions in prevent medicine. However, there are limitations in this study. First, the sample size was limited. In the future, these results should be confirmed in a large sample size. Second, due to the first limitation, whether the results are statistically insignificant in gender when sample size in each group increases cannot be indicated from this study. Finally, the population of this study is relatively young; the findings may not be the same as those in old population. However, the results still propose that FIR treatment may have beneficial effects represented on old population and may be coordinated for health care as well as complimentary and alternative therapies in clinical applications.

IV. CONCLUSIONS

This is the first study to assess the effects of FIR treatment on decreasing superoxide anions in human. Forty-six students aged 18-30 years old were recruited in this study to investigate the antioxidative effect of FIR in human by measuring the concentration of superoxide anions in blood of the recruited subjects receiving different arrangements of FIR hot compress. The results indicate that FIR treatment at the spine is effective in scavenging superoxide anions in blood, which merits further scientific investigations.

V. ACKNOWLEDGMENT

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VI. DISCLOSURE STATEMENT

No competing financial interests exist in this study.

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