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The Effects of Heat Application on the Immune Activities of the Human Body

The purpose of this study was to determine the effects of heat application on the immune activities of the human body. To exam, furthermore, the immune effect from the healthy volunteer(male:15, female:15) by monitoring changes of immune substances such as various leukocytes[total white blood cell(WBC), eosinophil, neutrophil, basophil, monocyte, and lymphocyte], a comparative study with warm water immersion(40.8±0.3℃) and infrared(250W) was carried out. The plasma analysis showed that the count of white blood cell, eosinophil, and neutrophil were elevated in warm water immersion- or infrared-stimulated group compared with control group. However, the count of basophil was decreased in both warm water immersion- and infrared-stimulated group than control group. Therefore, these results suggest that the thermostimulation improved immune activity.

Key words : *immune system; infrared; leukocyte; lymphocyte; warm water immersion.*

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INTRODUCTION

All animals including human beings are exposed to invasion of virus and microorganisms that may manifest as disease. In order to survive in an environment with such exposure, the human body acquires an immune system. The immune system is designed to protect the host body from pathogenic cells. Immunity is described commonly as either congenital or acquired(1). It is the acquired immunity that truly works as the protective mechanism in human bodies. The immune system of the human body has three important features. The first is the specificity of the immune system which allows for defense mechanism to exist. Foreign cells are detected by cell specific substances found inside or on the surface of cells. If the foreign cells are detected as pathogenic, the body induces an antigen-antibody reaction to attack the foreign pathogenic cell. Another feature is known as the unspecific humoral system. In this process, the complement system and plasma protein factors further divides and destroy the antigen-antibody complex that eventuates in an inflammatory reaction. The final feature involves the unspecific cellular system. In this system, leucocytes and macrophages involved in phagocytosis occurs to destroy the pathogenic cell and antigen-antibody complexes(2). In this way, leucocytes and lymphatic system are allowed to contribute significantly to immune reaction.

The white blood cell(WBC) includes granulocyte, lymphocyte and monocyte. The granulocyte is further classified into neutrophil, eosinophil or basophil depending on the form and reaction flame color of granule in the cytoplasm. These components of the WBC which are created in the hepatocyte and travels through the blood have an important function in defending the host organism against infection through phagocytosis and antibody formation(3). In addition, leucocytes are able to migrate through vas

cular walls and are known as the ameboid movement. Furthermore, leucocytes and related reaction such as phagocytosis may be triggered by the presence of bacteria, degraded products or an antigen-antibody complex(2). Having provided a forementioned information, a healthy and disease resistant body would depend on the ability of the body's immune system in response to invasion of pathogenic cells.

Treatments that aim to maintain the body's homeostasis as well as improve physiological action utilises the properties of heat. This may be in the form of infrared rays, hot packs, warm water immersion or high-frequency wave ultrasound(4). Warm water immersion has been shown to be physiologically effective in improving circulation, local metabolism and pain. When used in conjunction with infrared rays, a study showed the physiological effects such as thermogenesis, erythemogenic effect, pigmentation changes, sedative effect which was proposed to be through vasodialation and hyperemia. It was also shown that this treatment modality was effective in reducing inflammation and muscle cramps(5). Various studies have shown the physiological effect of thermal therapy to be a valuable source of modality for treatment of cancer. However, there are not enough evidence and studies regarding the effects of heat application on the immune system of the human body. Therefore, this study examined the effects of heat therapy on the immune system by observing immunoreactant activities including leucocytes in healthy volunteers.

METHOD

Subjects

15 healthy male(age 23~32yrs, height 171.0±1.2㎝, body weight 68.0±2.2㎏) and 15 healthy female (age 22~24, height 159.5±1.2㎝, body weight 54.6±2.4㎏) were recruited from Yongin university(Yongin, Korea). The study environment maintained a controlled tempera-ture of 23±1℃. In addition, the menstrual period of female volunteers was avoided and no mention of studies and blood were collected in constant time(14:00~16:00).

Application of warm water immersion and infrared radiation

In this study, warm water immersion and infrared radiation were applied to both feet. After having filled the automatic thermoregulation hot pack units(KRS 12P, Karis Co., Korea) with water, temperature was set at 42℃. Temperature changes were measured with a mercury thermometer before and after immersion(40.8±0.3℃)(6, 7). The immersion position for all subjects was in a sitting position with knees flexed at 90℃. Experimental area was controlled by water covering up to upper 1/3 of both medial malleolus for 30minutes twice accumulating. 60 minutes of immersion time in total. Infrared ray was set at output of 250W in standing that was 20~25 cm in height and applied at 90° angles to the area previously immersed in the warm water. Infrared was applied twice for 30 minutes each, totaling 60 minutes of application time. The position of subjects for this modality was in long sitting.

Blood collection and analysis

Plasma and serum samples were obtained to measure changes regarding eosinophil, neutrophi, basophil, monocyte and lymphocyte. After the second heat application, blood samples of 8 to 10ml were collected from the left right cubital vein while subjects maintained their position. Sepcial care was taken to obtain, blood samples within one or two minutes just after the second heat application in constant time(14:00~16:00)(8, 9). About 2~3ml of blood samples were refrigerated in the exclusive use tube that was used to process EDTA(ethylenediaminetetraacetic acid). Other 7~8ml of blood samples were put in a glass tube at the same time and the serum was divided in 3,000rpm with centrifuge for 10 minutes. Separated serum was removed with the serum separation officials, and refrigerated until measurement time. Analysis of WBC, eosinophil, neutrophil, basophil, monocyte and lymphocyte were performed through cytometry(Greencross Laboratory, Yong-in, Kyunggido).

Data analysis

SAS software(version 6.12) was used to analyse this study with each set of results to calculate the average and standard deviations. The level of significance was set at α=0.05, t-test and one-way ANOVA were used. Values were considered significantly different at $p<0.05$. The results are expressed as means±SEM.

RESULTS

Effects of RBC(erythrocyte) and hemoglobin, hematocrit by heat application

The changes in the count of RBC(erythrocyte) by heat application, did not show significant difference with warm water immersion group(male; $5.1\pm0.1\times10^6/\mu\ell$, female; $4.4\pm0.1\times10^6/\mu\ell$) or with infrared radiation group (male; $5.0\pm0.1\times10^6/\mu\ell$, female; $4.3\pm0.1\times10^6/\mu\ell$) compared with the control group(male; $5.1\pm0.1\times10^6/\mu\ell$, female; $4.4\pm0.1\times10^6/\mu\ell$) in both male and female(Fig. 1A, 1B).

The changes in the count of hemoglobin by heat application, did not show significant difference with warm water immersion group(male; 15.4 ± 0.2 g/dℓ, female; 13.1 ± 0.2 g/dℓ) or infrared radiation group(male; 15.1 ± 0.2 g/dℓ, female; 12.9 ± 0.2 g/dℓ) compared with the control group(male; 15.3 ± 0.3 g/dℓ, female; 13.3 ± 0.2 g/dℓ) in both male and female(Fig. 1C, 1D).

Similar results were shown in the count of hematocrit by heat application with warm water immersion group(male; 44.6 ± 0.6%, female; 38.7 ± 0.5%) or with infrared radiation group(male; 43.2 ± 0.6%, female; 37.5 ± 0.6%) compared with the control group(male; 44.3 ± 0.6%, female; 39.5 ± 0.5%) in both male and female(Fig. 1E, 1F).

Effects of WBC, eosinophil, basophil, neutrophil, monocyte and lymphocyte by heat application

The count of WBC by heat application, increased with warm water immersion group(male; $7.2\pm0.5\times10^3/\mu\ell$, female; $7.4\pm0.4\times10^3/\mu\ell$) compared with the control group(male; $6.5\pm0.5\times10^3/\mu\ell$, female; $7.2\pm0.4\times10^3/\mu\ell$) in both male and female(Fig 2A, 2B). The results for heat application without gender differentiation, showed that WBC counts increased with warm water immersion group($7.3\pm0.3\times10^3/\mu\ell$) compared with the control group($6.8\pm0.3\times10^3/\mu\ell$). However,

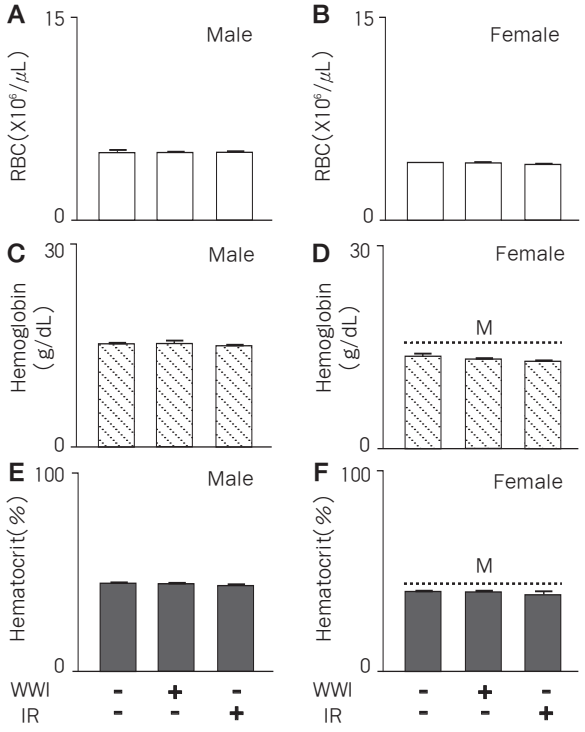

Fig. 1. Effects of warm water immersion and infrared on RBC, hemoglobin, and hematocrit in healthy subjects.(RBC; red blood cell, WWI; warm water immersion, IR; infrared, M; male.)

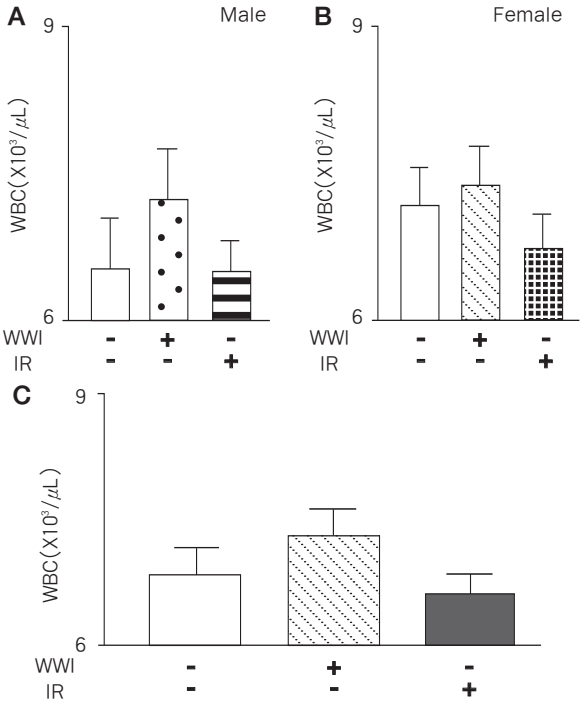

Fig. 2. Effects of warm water immersion and infrared on white blood cell in healthy subjects.(WBC; white blood cell, WWI; warm water immersion, IR; infrared, M; male.)

it did not show significant difference with infrared radiation group(male; 6.5±0.3×10³/㎕, female; 6.7±0.3×10³/㎕) compared with the control group(Fig. 2C). The results for heat application without gender differentiation showed significant difference between the infrared radiation group(6.6±0.2×10³/㎕) compared with the control group(6.8±0.3×10³/㎕).

The changes in the count of eosinophil by heat application increased with the warm water immersion group(2.3±0.3%) and the infrared radiation group(2.5±0.3%) compared with the control group(1.9±0.4%) regarding the females(Fig. 3B). However, it did not show significant difference between the warm water immersion group(3.3±0.6%) and the infrared radiation group(3.3±0.5%) compared with the control group(3.2±0.5%) regarding males(Fig. 3A). The results for heat application without gender differentiation increased with the warm water immersion group(2.8±0.3%) and the infrared radiation group(2.9±0.3%) compared with the control group(2.5±0.3%)(Fig. 3C).

The change in the count of basophil by heat application significantly decreased in the warm water immersion group(male; 1.0±0.1%, female; 0.8±0.1%) and the infrared radiation group(male; 0.9±0.1%, female; 0.7±0.1%) compared with the control group(male; 1.3±0.2%, female; 2.1±0.4%)(Fig. 4A, 4B). The results for heat application without gender differentiation decreased with warm water immersion group(0.90.1%) and the infrared radiation group(0.8±0.0%) compared with the control group(1.7±0.2%)(Fig. 4C).

The change in the count of neutrophil by heat application increased with the warm water immersion group(55.7±2.2%) and the infrared radiation group(58.8±2.1%) compared with the control group(54.5±2.0%) regarding males(Fig. 5A). However, it did not show significant difference between the warm water immersion group(59.8±1.9%) and the infrared radiation group(58.5±1.2%) compared with the control group(59.0±2.3%) regarding females(Fig. 5B). The results for heat application without gender differentiation increased in the warm water immersion group(57.7±1.5%) and

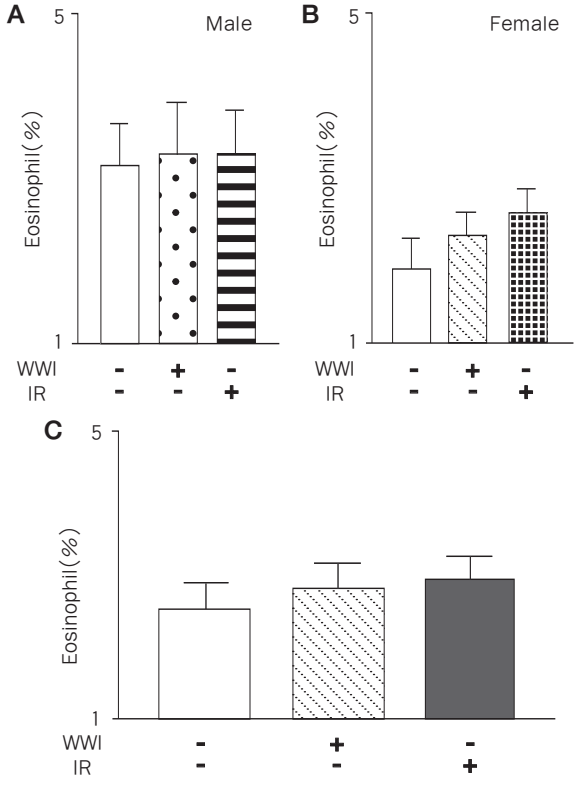

Fig. 3. Effects of warm water immersion and infrared on eosinophil in healthy subjects.(WWI; warm water immersion, IR; infrared, M; male)

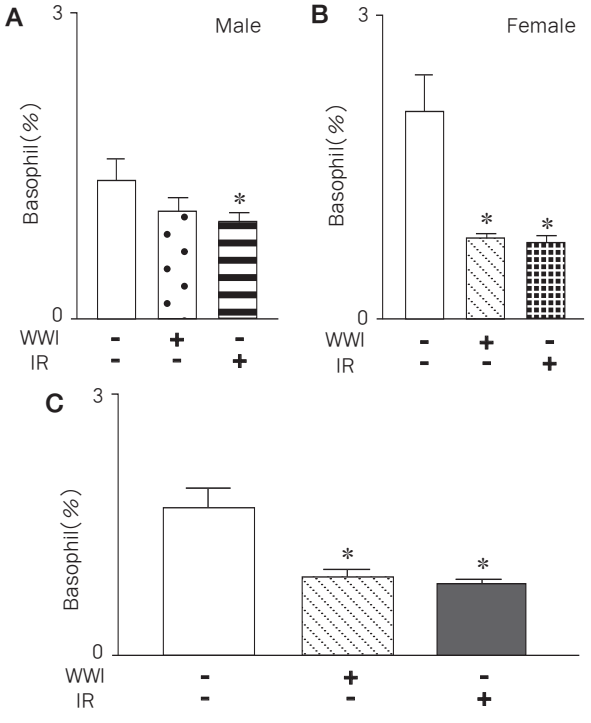

Fig. 4. Effects of warm water immersion and infrared on basophil in healthy subjects.(*: p<0.05)(WWI; warm water immersion, IR; infrared, M; male)

the infrared group(58.6±1.2%) compared to the control group(56.8±1.5%)(Fig. 5C).

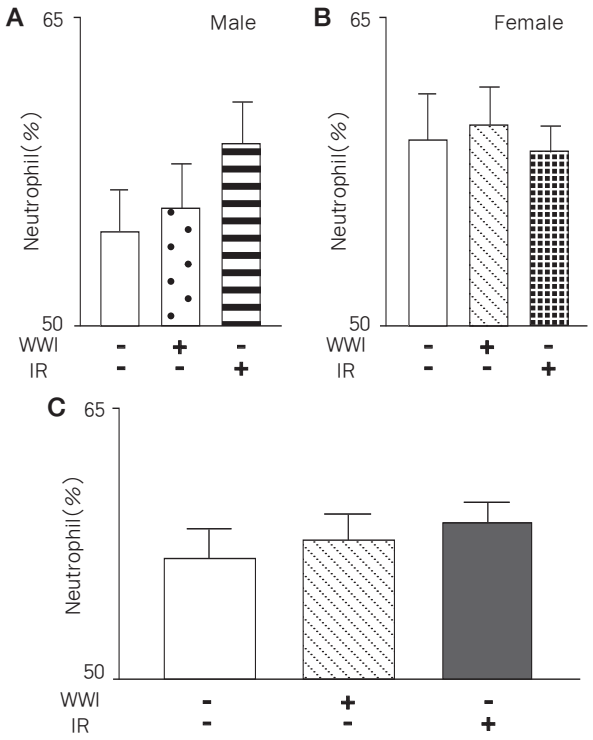

Fig. 5. Effects of warm water immersion and infrared on neutrophil in healthy subjects.(*,: p<0.05)(WWI; warm water immersion, IR; infrared, M; male)

The change in the count of monocyte and lymphocyte by heat application did not show significant difference with the warm water immersion group(monocyte-male; 5.5±0.4%, monocyte-female; 4.7±0.4%, lymphocyte-male; 34.5±1.8%, lympho-cyte-female; 32.5±1.9%) and the infrared radiation group(monocyte-male; 5.6±0.3%, monocyte-female; 4.3±0.3%, lymphocyte-male; 31.4±2.0%, lympho-cyte-female; 34.0±1.3%) compared with the control group(monocyte-male; 5.8±0.4%, monocyte-female; 4.9±0.4%, lymphocyte-male; 35.1±1.9%, lympho-cyte-female; 32.2±1.9%)(Fig. 6A, 6B, 7A, 7B).

The results for heat application without gender differentiation did not show significant difference with warm water immersion group(monocyte; 5.1±0.3%, lymphocyte; 33.5±1.3%) and the infrared radiation group(monocyte; 4.90.2%, lymphocyte; 32.7±1.7%) compared with the control group(monocyte; 5.4±0.3%, lymphocyte; 33.6±1.4%)(Fig. 6C, 7C).

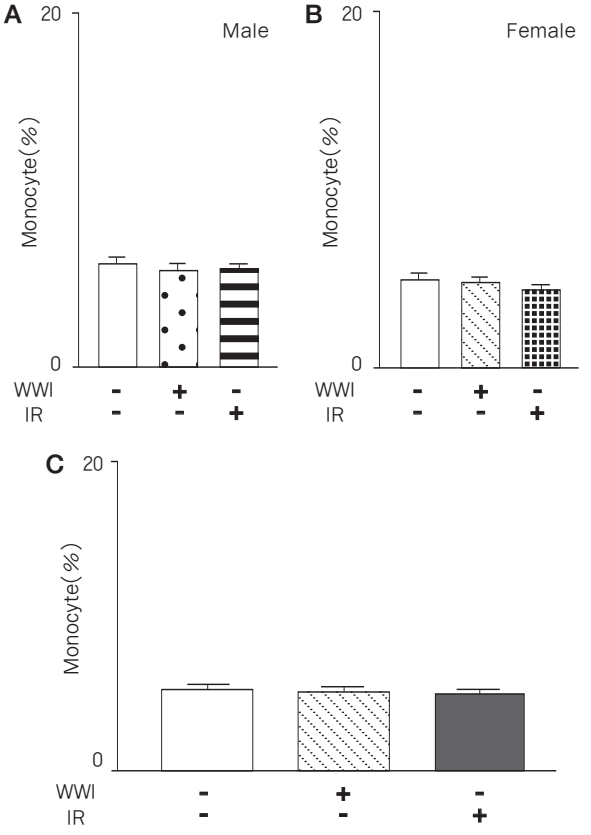

Fig. 6. Effects of warm water immersion and infrared on monocyte in healthy subjects.(*: p<0.05)(WWI; warm water immersion, IR; infrared, M; male)

DISCUSSION

The defense system of the human body against disease is commonly described as either congenital or acquired, the latter defining the entity of the immune system(10). It has been shown that the most active substance that has a role in the immune function is the leukocyte. Leukocytes comprise of granulocyte, lymphocyte and monocyte to act as a primary defense system against invasion of bacteria, foreign body, toxic substance and etc. It then destroys bacteria and produces immunoglobulin.

Heat application has been renowned for its role in the maintenance of health and homeostasis of human body since the ancient times. Various methods have been able to induce heat, including warm water immersion and infrared radiation. Warm water immersion leads to dilatation of blood capillaries, arteries and veins and increases blood flow. As a result, blood vessels of internal organs constricts which decreases the resistance of peripheral vessels

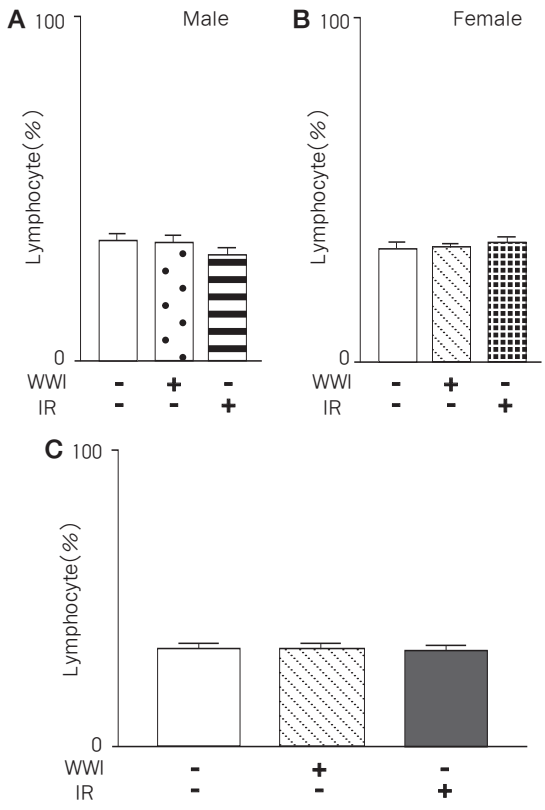

Fig. 7. Effects of warm water immersion and infrared on lymphocyte in healthy subjects.(WWI: warm water immersion, IR: infrared, M: male)

and increases the velocity of the blood flow(11). The effects of infrared radiation on the human body include increase in blood flow rate, sweat, metabolism, excretion of wastes and alleviation of pain. It is important to note that leucocyte levels are increased through infrared radiation along with increased opsonization activity and anti-inframmatory effects. Promotion of waste excretion also occurs subsequent to increase in lymphatic circulation(5).

In 1980 Farjardo et al. found that heat application of 44℃on tumor cell for 30 minutes had led to a considerable breakdown on the cell's membrane. Six hours later, nuclear contraction was observed, which led to a conclusion that heat application has the effect of suppressing disease outbreak as well as healing. In a more present study, Engin reported that heat therapy and chemotherapy had effects for treatment of a malignant tumor(e.g., brain tumor, ovarian tumor, breast cancer)(12). In this study, changes in leukocyte levels were observed which correlated with the body's change in resistibility through heat application. Comparison between each of the groups in terms of the changes in count of WBC post heat application increased with warm water immersion group. Moreover, eosinophil and neutrophil levels were increased in the warm water immersion group and the infrared radiation group compared with the control group. These results revealed that the resistibility of the human body and phagocytosis of an outside antigen was activated and promoted by heat application, which is also confirmed by the data in the report of other researchers (13, 14, 15). In contrast, the count of basophil levels were significantly decreased in warm water immersion group and infrared radiation group compared to the control group. It is particularly important that the basophil which produces inflammation related materials such as histamin, leukotriene, chemotactic factor and prostaglandin(16, 17) was significantly decreased in the warm water immersion group and in the infrared radiation group. Thus, these results imply that heat application is effective in inflammation depression.

CONCLUSION

This study suggested that WBC, eosinophil and neutrophil levels were significantly increased post warm water immersion application and infrared application to the human body. In contrast, basophil level was significantly decreased. However the results are based on a small sample and additional studies are needed.

REFERENCES

1. No SD. The effect of walking training on immune reaction. Dept. of Physical education, Graduate School, Dong-A University, Korea 1998: 58-97.
2. Hong SK. Human Physiology. Korea medicine 1999: 377-315.
3. Cha SW. The effects of aerobic exercise training on immunity function, body composition and blood components in obese high school girls. Dept. of Physical education, Graduate School, Pusan University, Korea 1999: 79-113.
4. Kim SH, Kim KJ, Min KO, Kim SY, Moon OK, Park JH., Seo HK, Song MS, Yoon NM, Lee KH,

Choi WS, Hong WS. Physical Therapy for musculoskeletal system and Circulatory system, Hanulbook 2006: 13-15.
5. Kim SH, Moon OK, Lee JH, Phototherapy. Hanulbook 2008: 141-158.
6. Ahlers O, Hildebrandt B, Dieing A, Deja M, Bohnke T, Wust P, Riess H, Gerlach H, Kerner T. Stress induced changes in lymphocyte subpopulations and associated cytokines during whole body hyperthermia of 41.8-42.2℃. Eur J Appl Physiol 2005; 95(4): 298-306.
7. Allison TG, Reger WE. Comparison of responses of men to immersion in circulating water at 40.0 and 41.5℃. Aviat Space Environ Med 1998; 69(9): 845-850.
8. Lutz HU, Stammler P, Jelezarova E, Nater M, Spath PJ. High doses of immunoglobulin G attenuate immune aggregate-mediated complement activation by enhancing physiologic cleavage of C3b in C3bn-IgG complexes. Blood 1996; 88(1): 184-193.
9. Pangburn MK, Rawal N. Structure and function of complement C5 convertase enzymes. Biochem Soc Trans 2002; 30(Pt 6): 1006-1010.
10. Kim HJ. Effect of intensity on cellular immune response in untrained women, Dept. of Physical education, Graduate School, Korea National University of Education 2000: 32-57.
11. Min KO. Thermal-Hydrotherapy. Daehakseorim 1993: 236-259.
12. Engine K. Hyperthermia in cancer treatment. Neoplasm 1994: 41:5.
13. Jokinen E, Valimaki I, Marniemi J, Seppanen A, Irjala K, Simell O. Children in sauna: hormonal adjustments to intensive short thermal stress. Acta Physiol Scand 1991; 142(3): 437-442.
14. Kappel M, Stadeager C, Tvede N, Galbo H, Pedersen BK. Effects of in vivo hyperthermia on natural killer cell activity, in vitro proliferative responses and blood mononuclear cell subpopulations. Clin Exp Immunol 1991; 84(1): 175-180.
15. Niwa Y, Iizawa O, Ishimoto K, Jiang X, Kanoh T. Electromagnetic wave emitting products and "Kikoh" potentiate human leukocyte functions. Int J Biometeorol 1993; 37(3): 133-138.
16. Cotran RS, Kumar V, Collins T. Pathologic basis of disease, 6th ed. W.B. Saunders Co 1999: 1126-1178.
17. Roitt IM. Essential immunology, 8th ed. Blackwell scientific publications 1994.