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Original Article

Evaluation of tympanic temperature and thermal sensation responses during exercise to verify the positive effects of wearing germanium-coated functional clothing

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Abstract. [Purpose] The present study investigated the effects of wearing germanium-coated functional clothing on tympanic temperature, thermal sensation, heat shock protein 70 (Hsp70), and lactate during endurance exercise. [Subjects and Methods] Nine healthy and untrained male subjects were enrolled. Subjects ran for 60 min on a treadmill (75% heart rate reserve) in the following 2 tests: 1) control test (wearing conventional clothing) and 2) experimental test (wearing germanium-coated functional clothing). During each test, the tympanic temperature and thermal sensation were measured, and blood samples were collected immediately before exercise and immediately after exercise. Thermal sensation was measured using a DISC score. [Results] The tympanic temperature immediately after exercise was significantly increased compared to the temperature immediately before exercise in the control test, while no significant change was observed in the experimental test. In both tests, the DISC score and Hsp70 and lactate levels immediately after exercise were significantly increased compared to those immediately before exercise. In addition, the DISC score immediately after exercise was significantly higher in the control test than in the experimental test. [Conclusion] Wearing germanium-coated functional clothing during endurance exercise may have the positive effect of alleviating thermal stress that accumulates in the body during exercise.
Key words: Germanium, Endurance exercise, Thermoregulation

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INTRODUCTION

Prolonged endurance exercise causes an elevation in body temperature. The body controls its temperature through perspiration to maintain homeostasis. However, insufficient body water due to continuous dehydration caused by prolonged exercise leads to a decrease in plasma volume and cardiac output and an increase in plasma osmolarity and core temperature[1, 2)]. Furthermore, inefficient heat dispersion caused by a decreased rate of blood flow to the skin can accelerate fatigue and deteriorate exercise performance by retaining body heat[3, 4)]. Therefore, to improve exercise performance in athletes and to enhance the effects of regular exercise for health maintenance and promotion, it is important to develop a method that can alleviate exercise-induced rise in body temperature.

Far infrared electromagnetic wavelengths of 5.6–1,000 μm can activate cells and promote metabolism when absorbed by the human body. Germanium (Ge) emits far infrared rays. Previous studies verified the efficacy of Ge-coated clothing[5, 6)],

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and observed that Ge-containing fibers emitted far infrared rays and anions and had an antibacterial effect. These results suggested that Ge-containing fibers could promote blood circulation and had the potential to suppress fatigue and relieve thermal stress by wearing Ge-containing and/or Ge-coated clothing during exercise. However, a scientific approach to proving such an effect has been very limited.

Therefore, the present study aimed to investigate the effects of wearing Ge-coated functional clothing during exercise on tympanic temperature; thermal sensation; heat shock protein 70 (Hsp70), which is involved in homeostatic regulation in exercise-induced thermal stress; and lactate, an indicator of fatigue.

SUBJECTS AND METHODS

Nine healthy and untrained male subjects (age: 20.2 ± 0.4 years; height: 175.7 ± 2.8 cm; weight: 73.1 ± 10.1 kg; body mass index: 23.7 ± 3.0 kg/m^2; muscle mass: 34.6 ± 2.9 kg; fat mass: 12.4 ± 6.2 kg; percentage body fat: 16.3 ± 6.3%; resting heart rate: 70.9 ± 3.6 beats/min; systolic blood pressure: 118.6 ± 7.3 mmHg; diastolic blood pressure: 72.6 ± 8.4 mmHg) volunteered as subjects for the present study. The study was conducted in accordance with the standards set by the latest revision of the Declaration of Helsinki, and all the subjects provided written informed consent in accordance with the Department of Sport for All Studies at Soongsil University guidelines.

Anthropometric measurements included height, body composition, resting heart rate, and blood pressure. Height and body composition were measured using a stadiometer (SECA213; SECA, Germany) and a bioimpedance analysis device (Inbody720; Biospace, Korea), respectively. Resting heart rate and blood pressure were measured in a seated position, using a heart rate monitor (Polar a5; Polar, Finland) and a mercury sphygmomanometer (Trimline; PyMaH, USA), respectively.

The 9 subjects participated in control and experimental tests, both involving 60 min of running on a treadmill at an exercise intensity of 75% heart rate reserve in a laboratory with temperature and humidity of 18.5 ± 0.5 °C and 36.0 ± 1.0%, respectively. The clothing worn by each subject consisted of a half-sleeve T-shirt and short pants. During the control test, the participants wore conventional clothing (which had not received functionality treatment); during the experimental test, they wore Ge-coated functional clothing (which had been prepared by coating the same clothing used for the control test with Ge). According to the result of a comparison test using Fourier transform infrared spectroscopy (FT-IR) and a black body at 37 °C, which is almost the same as body temperature, the far infrared rays emitted by the Ge-coated functional clothing characteristically showed an emission rate of 0.893 μm and a wavelength of 3.44 × 10^2 W/m^2·μm.

Tympanic temperature was measured using infrared ear thermometry (Thermoscan IRT-4520; Braun, Germany) as a surrogate for core temperature. Thermal sensation was measured using a DISC score[7].

Using a 22-gauge needle, a serum separator tube (Becton Dickinson, USA), and an ethylenediaminetetraacetic acid-coated tube (Becton Dickinson, USA), 8 mL of blood was collected from the antecubital vein of each subject immediately before exercise (IBE) and immediately after exercise (IAE). The collected blood samples were centrifuged for 15 min at 3,000 rpm, and then stored at −80 °C until analysis. The serum Hsp70 levels were determined using a high-sensitivity, commercially available enzyme-linked immunosorbent assay (ELISA) kit (Assay Designs, USA). The absorbance was measured at 450 nm with a microplate reader (EMax; Molecular Devices, USA). The plasma lactate levels were determined using a clinical chemistry analyzer (Ektachem DT 60; Eastman Kodak, USA).

Statistical analyses were performed using SPSS software, version 21.0 for Windows (SPSS Inc., USA). Data are presented as mean ± standard deviation (SD). For identifying differences in normally distributed results, a two-way repeated analysis of variance (ANOVA) was performed. When significant time by trial interactions occurred, simple main effects were assessed using the independent and paired t-tests. Statistical significance was set at $p<0.05$.

RESULTS

The tympanic temperature, DISC score, Hsp70, and lactate levels are presented in Table 1. The tympanic temperature IAE was significantly elevated compared to the temperature IBE in the control test ($p<0.05$), while no significant change was observed in the experimental test. In both tests, the Hsp70 and lactate levels measured IAE were significantly increased

Table 1. Germanium-coated functional clothing effects on tympanic temperature, DISC score, Hsp70, and lactate levels

Variable	Control (n=9)		Experimental (n=9)	
	IBE	IAE	IBE	IAE
Tym T (°C)	36.41 ± 0.44	37.16 ± 0.68*	36.73 ± 0.30	37.16 ± 0.66
DISC score[a]	−1.33 ± 0.87	2.44 ± 1.13*	−1.22 ± 0.97	1.11 ± 1.17*#
Hsp70 (ng/ml)	0.184 ± 0.017	0.205 ± 0.027*	0.193 ± 0.017	0.210 ± 0.019*
Lactate (mmol/l)	1.48 ± 0.60	2.84 ± 1.34*	1.12 ± 0.45	2.03 ± 0.89*

Data are presented as mean ± SD. Tym T: tympanic temperature; IBE: immediately before exercise; IAE: immediately after exercise; [a]Rating scale range, −3 to 4; *$p<0.05$ vs. IBE; #$p<0.05$ vs. control test

compared to the levels IBE ($p<0.05$). However, there was no significant difference between the control and experimental tests. The DISC score IAE was significantly increased compared to the score evaluated IBE in both tests ($p<0.05$), and it was significantly higher IAE in the control test compared to that in the experimental test ($p<0.05$).

DISCUSSION

Organic Ge has been reported to promote immune activation and play an important role in regulating antioxidative activities[8, 9]. For this reason, it has been widely utilized for manufacturing not only health functional foods but also bracelets, necklaces, and textile products such as underwear. To verify the effects of wearing Ge-coated functional clothing during exercise on thermal stress, in the present study, the tympanic temperature, thermal sensation, and serum Hsp70 levels were measured. The results in the control test (wearing common clothing) showed a significant increase in tympanic temperature measured IAE; however, the experimental test (wearing Ge-coated clothing) did not show such an increase. In addition, the measurement of thermal sensation using the DISC score showed significantly lower levels IAE in the experimental test than that in the control test. The reasons for such results could be that Ge-coated clothing alleviated exercise-induced thermal stress by promoting blood circulation during exercise. This interpretation is supported by the observations that increase in skin blood flow during exercise is an effective mechanism for dispersing heat accumulated in the body[10], and that Ge-containing clothing had the effect of promoting blood circulation[5, 6]. In both tests in the present study, the serum Hsp70 and plasma lactate levels showed a significant increase IAE, but without a significant difference between the 2 tests. The result for Hsp70 levels supports the results of previous studies that reported a significant increase after acute exercise[11, 12], and suggests that not only high core temperature but also various other factors contribute to Hsp70 expression. This interpretation is consistent with the reports of a positive correlation between Hsp70 expression and core temperature[13]; however, Hsp70 expression was also affected by various physiological and environmental stress factors such as heat, training status, oxidative stress, pH change in the body, and glucose depletion[14, 15]. Conversely, the lactate level is considered independent of thermal stress, probably due to the same level of exercise intensity used for both tests; this result suggests that wearing Ge-coated clothing during exercise exerts no significant effect on exercise-induced fatigue. This interpretation is supported by Ishii and Nishida, who reported that circulating lactate concentrations were dependent on exercise intensity[16], and also by Mohr et al., who reported that exercise under different environmental conditions (21 °C vs. 43 °C) showed no difference in plasma lactate concentration in spite of significant differences in core temperature[17].

In conclusion, the present study suggests that wearing Ge-coated clothing during endurance exercise may have the positive effect of alleviating thermal stress that accumulates during exercise.

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