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Thermographic Study on the Preservability of Heat Effects of Footbath with Salt

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ABSTRACT

Infrared thermography provides a non-invasive and dynamic measure of heat. The thermal preservability effects of a salt footbath were evaluated by the infrared thermography technique. The subjects were 23 healthy college students. Feet were soaked for 10 min in a 40-42°C normal footbath. Room temperature was set at 26.5-28°C. At the same time on another day within 3 days of the normal footbath experiment, the same feet were soaked for 10 min in a 40-42°C salt footbath. We measured blood pressure, heart rate and temperatures of the feet, second toes, hands and middle fingers, just before and after immersion and at 10-min intervals thereafter. Mean blood pressure changes showed no difference between the normal and the salt footbath. Mean heart rate changes were higher during the normal footbath than at 0, 15 and 20 min during the salt footbath, respectively ($p<0.05$). Mean thermal preservability of the feet tended to be lower after the normal footbath than at 20 and 30 min, respectively, after the salt footbath, but these differences did not reach a statistical significance. Mean thermal preservability of the hands and middle fingers was significantly lower after the normal footbath than at 20 and 30 min, respectively, after the salt footbath ($p<0.05$). The results suggest that stimulation by a salt footbath affects surface skin temperature, and that stimulation aimed at increasing skin thermal preservability shows a significant difference between normal and salt footbaths.

Key words: *Nursing arts, Salt footbath, Skin thermal preservability, Infrared thermography technique*

The footbath has long been used and it is one of the caring techniques and services of nurses employed in medicine. A footbath is used in aromatherapy, spa therapy and balneotherapy for treating various skin disorders, for relaxation to improve sleeping, for postoperative pain and for controlling infection[1,2,4-6]. A footbath can enhance the body's immunity and resistance, with concomitant effects on physical health and longevity[2,4-8]. A footbath is a mixture of herbs, salts, moisturizers or other ingredients that is added to a container of warm water and used for soaking the feet. Anyone who takes a hot spring bath feels its residual heat for a while after bathing because of the inorganic salts it contains[6-11]. The thermal preservability of domestic bath preparations derived from hot springs is premised on the effectiveness of hot springs. Inouye et al studied the effect of essential oils and salt footbaths on fungicidal activity[3,5]. We speculate that there is the same thermal preservability effect after a salt footbath as after a hot spring. To confirm our hypothesis, we used an infrared thermographic technique to measure the skin surface temperature. This infra-red thermography technique makes it possible to overcome limitations inherent to contact measuring means traditionally used in thermal studies. The purpose of this work was to determine experimentally the thermal preservability of a salt footbath.

SUBJECTS AND METHOD

The subjects were 23 healthy female college students (21-22 years in distribution). They were

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excluded if they had an acute illness, were undergoing chronic hemodialysis, or had diabetes, peripheral vascular or nerve diseases. The study content and method were sufficiently explained to all subjects, and written consent was obtained before the study. The Ethics Committee of the Prefectural University of Hiroshima approved this study. It was conducted in accordance with the Declaration of Helsinki.

The timetable of the experiment is shown in Fig. 1[6,7,11]. The subjects had 15 minutes' rest in the experimental chair (Fig. 2). After that a footbath was taken for 10 min in a 40-42°C normal footbath (volume 10 liters) up to 20 cm above the ankles, followed by 30 minutes' rest. We measured blood pressure and heart-rate every 5 min, and the skin temperature of the feet, second toes, hands and middle fingers, before and after the footbath, and at 10-min intervals thereafter (Fig. 1). Room temperature was set at 26.5-28°C. At the same time on another day within three days of the experiment with the normal footbath, a salt footbath (in which 400 g of salt was dissolved in 10 liters of water) was employed in the same way as the normal footbath[6,7,11]. We removed hot water or hot salt water from the feet after the footbath. Temperature measurements on the skin surface were taken using an infrared thermocamera (Thermal imager InfRec R300, NEC Avio Infrared Technologies Co., Ltd., Tokyo, Japan) with a thermal resolution of 0.05°C, temperature accuracy of ± 1°C and spatial resolution of 120 μm. Images were recorded. Selected thermographic images were processed with InfReC Analyzer NS9500 Standard (NEC Avio Infrared Technologies Co., Ltd., Tokyo, Japan). Data were analyzed with the Student's t-test. Probability values of 0.05 or lower were regarded as statistically significant in all tests. Statistical analysis was performed using StatView software (version 4.5; SAS Institute, Inc., Cary, NC).

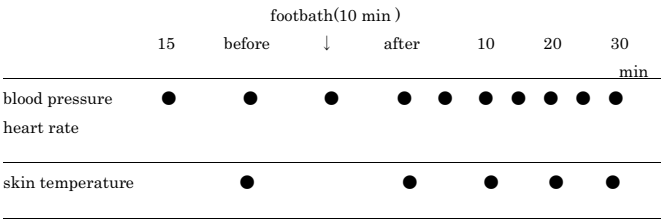

Fig. 1. Timetable of the experiment

Healthy female college students had 15 minutes' rest. After that a footbath was taken for 10 min, followed by 30 minutes' rest. We measured blood pressure and heart rate every 5 min, and skin temperature of feet, second toes, hands and middle fingers, before and after footbath, and at 10-min intervals thereafter.

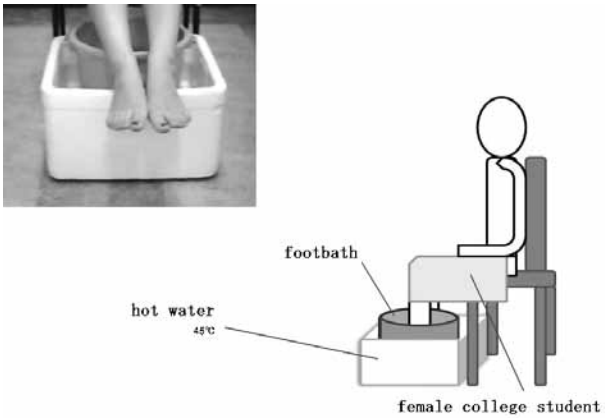

Fig. 2. Set up for the experiment

Healthy female college students had 15 minutes' rest in the experimental chair. Then they immersed their feet in a normal footbath, volume 10 litres, 40-42°C for 10 min up to 20 cm above the ankles. We removed hot or hot salt water from feet after the footbath. We measured blood pressure, heart rate and temperature of feet, 2nd toes, hands and middle fingers. Room temperature was set at 26.5-28°C. At the same time on another day within 3 days of the normal footbath experiment, a salt footbath (in which 400 g of salt was dissolved in 10 litres of water) was used in place of the normal footbath.

RESULTS

Mean blood pressure changes were not different between normal and salt footbaths (Fig. 3). Mean heart rate changes were higher in normal than at 0, 15 and 20 min in a salt footbath, respectively ($p<0.05$) (Fig. 4). Mean thermal preservability of the feet tended to be lower after a normal footbath than at 20 and 30 min after a salt footbath, respectively, but these differences did not reach a statistical significance (Fig. 5). Mean thermal preservability of second toes was not different between normal and salt footbath (Fig. 6). Mean thermal preservability of hands and middle fingers was significantly lower after the normal footbath than at 20 and 30 min after the salt footbath, respectively ($p<0.05$) (Fig. 7, 8).

DISCUSSION

The footbath has been practiced for centuries and has many proponents. It is especially recommendable for handicapped, elderly, and disabled persons who are unable to take regular baths easily and safely[1,6-8,12-14]. Regarding cerebral circulation, a footbath increases total hemoglobin concentration in the forehead[11]. After a footbath, foot temperature is considerably elevated. Lower leg temperature, hand temperature, and finger temperature rise significantly with passage of time, showing that a footbath not only raises the skin temperature locally, but also raises the temperature in the hands and fingers, thus providing a warmth retention effect for the entire body[6,7,10,11]. A foot bath brings warmth to the entire body. It is also effective in improving peripheral blood circulation. Despite fierce debate about its efficacy there has been little scientific

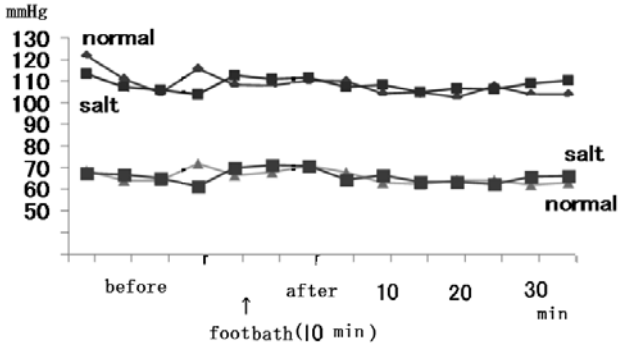

Fig. 3. Blood pressure changes before and after normal and salt footbaths

Mean blood pressure changes showed no difference between normal and salt footbath. Triangle points (▲) indicate mean systolic and diastolic blood pressure changes of normal footbath. Square points (■) show mean systolic and diastolic blood pressure changes of salt footbath.

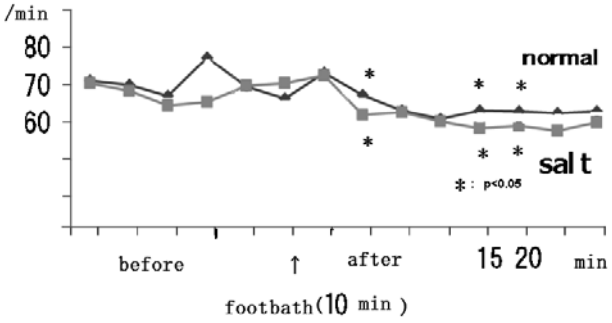

Fig. 4. Heart rate changes before and after normal and salt footbaths

Mean heart rate changes were higher in normal than those at 0, 15 and 20 min in salt footbath, respectively ($p<0.05$). Triangle points (▲) indicate mean heart rate changes of normal footbath. Square points (■) show mean heart rate changes of salt footbath.

*: $p<0.05$. Data were analyzed with the Student's t-test.

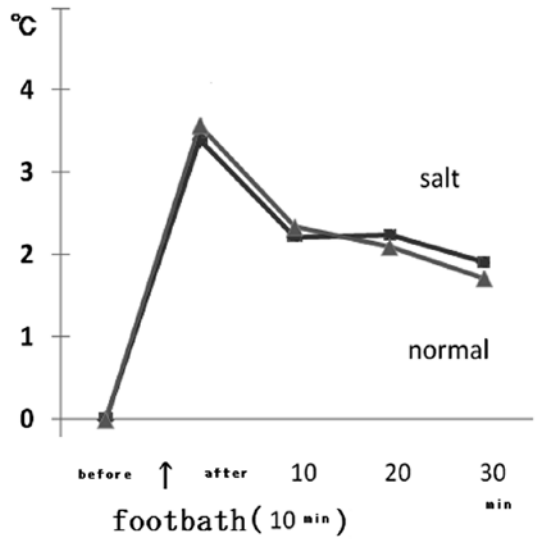

Fig. 5. Thermal preservability changes of feet after normal and salt footbaths

Mean thermal preservability of feet tended to be lower after normal footbath than at 20 and 30 min after salt footbath, respectively, but these differences did not reach a statistical significance. Triangle points (▲) indicate mean feet temperatures of normal footbath. Square points (■) show mean feet temperatures of salt footbath.

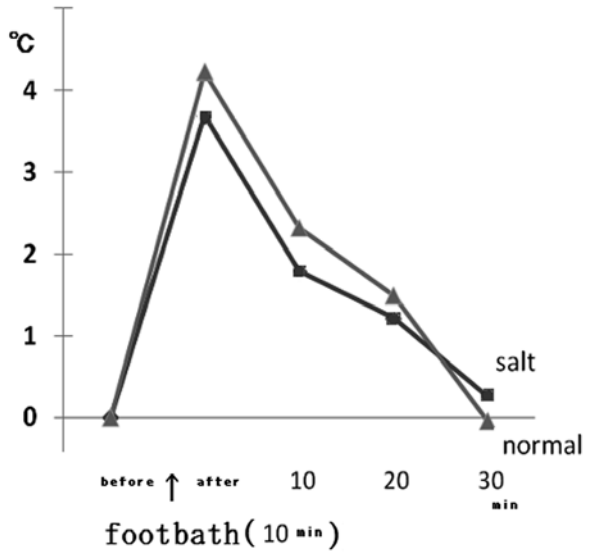

Fig. 6. Thermal preservability changes of second toes after normal and salt footbaths

Mean thermal preservability of second toes was not different between normal and salt footbath. Triangle points (▲) indicate mean second toe temperatures of normal footbath. Square points (■) show mean second toe temperatures of salt footbath.

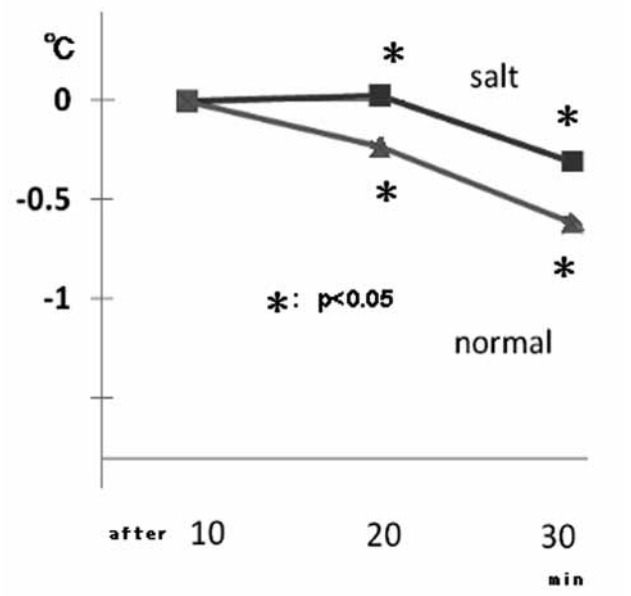

Fig. 7. Thermal preservability changes of hands after normal and salt footbath

Mean thermal preservability of hands was significantly lower after normal footbath than at 20 and 30 min after salt footbath, respectively ($p<0.05$). Triangle points (▲) indicate mean hand temperatures of normal footbath. Square points (■) show mean hand temperatures of salt footbath. ＊: $p<0.05$. Data were analyzed with the Student's t-test.

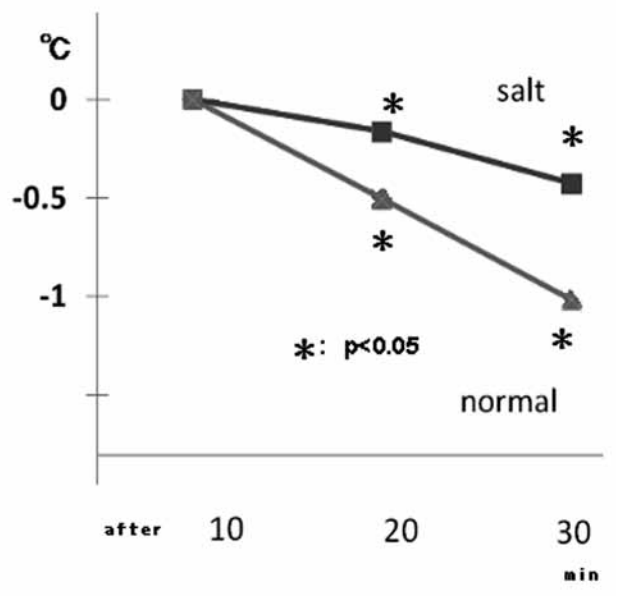

Fig. 8. Thermal preservability changes of middle fingers after normal and salt footbath

Mean thermal preservability of middle fingers was significantly lower after normal footbath than at 20 and 30 min after salt footbath, respectively ($p<0.05$). Triangle points (▲) indicate mean middle finger temperatures of normal footbath. Square points (■) show mean middle finger temperatures of salt footbath. ＊: $p<0.05$. Data were analyzed with the Student's t-test.

evaluation of the thermal preservability effect of a salt footbath.

We studied the thermal preservability of a salt footbath with an infrared thermography technique. Our data indicated that a salt footbath has a stronger effect on thermal preservability. Miyazato and Matsukawa examined the effect of a footbath on the cardiac parasympathetic outflow of women[9]. They found that a footbath decreases the cardiac parasympathetic outflow of women, because it does not significantly affect the systemic hemodynamics and body temperature but reduces the respiratory arrhythmia and the respiratory-synchronized component of the power spectrum of R-R interval variability with a fast Fourier transform. The hypothalamus is responsible for certain metabolic processes and other activities of the autonomic nervous system[6,7,9-12]. The hypothalamus controls body temperature. A salt footbath has an effect on circulation and thermal preservation in the limbs. Our results suggest that stimulation by salt footbath affects surface skin temperature, and that stimulation aimed at increasing skin thermal preservation showed a significant difference between a normal footbath and a salt footbath.

Anyone who takes a hot spring bath feels its remaining heat for a while after because of inorganic salts contained within the bath. Infrared thermography is a means of measuring the heat radiated from the skin surface, and has been used as a non-invasive tool in medicine since the 1960s. Infrared thermography of the skin temperature after the feet have been immersed in a salt footbath has made it possible to visualize variations in the temperature while being not only noninvasive but also avoiding touch. As a result, it reduces the risk of influence on skin temperature mechanically, being different from the conventional method with a thermometer.

A footbath is different from a bath of the whole body in its treatment conditions, and a relatively high temperature (42°C) and short immersion time (10 min) are recommended for footbaths[6,7,12]. Carbon dioxide-enriched water has been used as an alternative thermotherapy to treat intractable diabetic skin diseases. The thermal effect plays a dominant role in killing the fungal cells, when combined with heat and salt stress[5-7,9]. It is of interest to note that successful thermotherapy has been reported for subcutaneous infections[5]. Hyperthermia provides a potent therapeutic tool for cancer treatment. A footbath containing green tea polyphenols is effective in improving the symptoms of tinea pedis. Footbaths are also considered to provide a beneficial thermal therapy for post-stroke patients. A footbath, therefore, has frequently been employed as a therapeutic technique in daily nursing care.

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