Effects of Water Temperature during Foot Bath in Young Females

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ABSTRACT

We examined the effects of environmental and water temperatures of foot baths on pulse rate, blood pressure, mean skin temperature, salivary amylase (SA) activity, relaxation level and thermal sensation during winter. Five females participated in the study. The subjects rested in a chair for 20 min and the above-noted physiological reactions during the last 5 min of the resting period were recorded as baseline (BASE) values. Next, the subjects received a 15-min foot bath in water at 40 ˚C (WT40) or 45 ˚C (WT45), with a 15-min recovery period. Although SA is thought to be an indicator of stress via the sympathetic nervous system, we did not find a correlation between SA activity and relaxation state. We considered the possible effect of seasonal variation on the physiological reaction to foot bathing.

Key words foot; immersion; salivary alpha amylase; seasonal variation; thermosensing

Foot immersion is particularly effective for inducing relaxation and sleep. We hypothesized effects of environmental and water temperatures and seasonal variation on the physiological reaction to foot bathing, and examined the effects of both temperatures of foot baths on pulse rate, blood pressure, mean skin temperature, salivary amylase (SA) activity, relaxation level and thermal sensation during the winter.

SUBJECTS AND METHODS

Five female subjects participated in the study (age, 20.5 years, s = 1.0; height, 157.2 cm, s = 9.3; body weight, 53.9 kg, s = 6.5; body fat, 26.9%, s = 1.8). This study was approved by the Ethics Committee of Tottori University (approval number 2074).

All subjects wore T-shirts and shorts during the experiment. The room temperature was maintained at 20 ˚C. The subjects each rested in a chair for 20 min; pulse rate, blood pressure, mean skin temperature, SA activity, relaxation state and thermal sensation during the last 5 min of the resting period were recorded as baseline (BASE) values. Next, the subjects received a 15-min foot bath in water at 40 ˚C (WT40) or 45 ˚C (WT45), with a 15-min recovery period. Pulse rate, blood pressure and skin temperature were measured by digital electronic sphygmomanometer ES-P110 (Terumo, Tokyo, Japan) at the end of BASE recording and at 5, 10 and 15 min of the foot immersion and recovery periods.

Skin temperatures were obtained from the chest, arm and thigh using thermistor thermometer NT Logger N542R and thermistor probe ITP082-25 (NIKKISO-THERM, Tokyo), and mean levels were calculated.[1] SA activity was measured by Salivary Amylase Monitor (NIPRO, Osaka, Japan) at each end of BASE recording, foot immersion and recovery periods. SA activity is used as an indicator of stress via the sympathetic nervous system.[2, 3] The relaxation level and thermal sensation of the whole body and foot were similarly measured on a numerical rating scale. Foot baths under each condition (WT40 and WT45) were performed between 1100 hours and 1300 hours on different days, but always at the same time. The room temperature was maintained at 20 ˚C.

All data were presented as mean and standard deviation. A two-way analysis of variance with repeated measures was used to test for a physiological difference between water temperatures. Tukey's post-hoc test was used to test significant differences. The subjective scale was assessed by the Friedman and Wilcoxon signed rank tests. The data were analyzed using the PASW Statistics software for Windows ver. 18.0 (IBM, Tokyo, Japan). The significance level was set at $P < 0.05$.

RESULTS AND DISCUSSION

Compared to the BASE values, the pulse rate and systolic and diastolic blood pressures did not change under either bathing condition. Foot immersion probably puts a less severe load than usual bathing does on the circulatory system, and it induces hyperthermia.[4]

The main effect of time was significant for the mean skin temperature ($P < 0.05$). Mean skin temperature was

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Abbreviations: BASE, baseline recorded during the last 5 min of the 20-min resting period; SA, salivary amylase; WT40, 15-min foot bath in 40 ˚C water; WT45, 15-min foot bath in 45 ˚C water

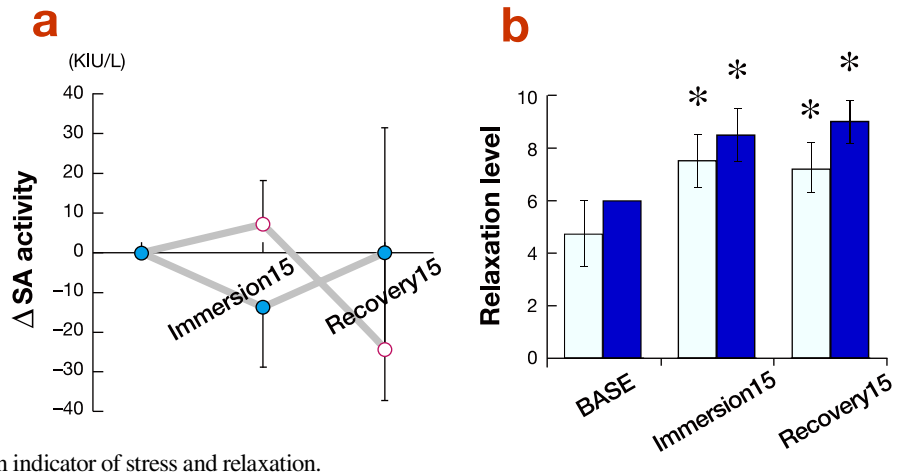

Fig. 1. Changes in an indicator of stress and relaxation.
a: Changes in SA activity under conditions of WT40 (○) and WT45 (●). The main effect of water temperature was marginally significant for SA activity ($P = 0.057$).
b: Changes in relaxation level under conditions of WT40 (□) and WT45 (■). Compared to the BASE values, the relaxation level under both conditions increased significantly during the foot immersion and recovery periods. *$P < 0.05$ versus BASE.
BASE, baseline recorded during the last 5 min of the 20-min resting period; Immersion15, measurement at the end of a 15-min foot immersion period; Recovery15, measurement at the end of a 15-min recovery period; SA, salivary amylase; WT40, 15-min foot bath in 40 ˚C water; WT45, 15-min foot bath in 45 ˚C water.

affected by the heat stimulation of the foot bath under both temperature conditions.

The main effect of water temperature was not significant for SA activity ($P = 0.057$) (Fig. 1a). We considered the possibility that cardiac vagal modulation was enhanced under the WT45 condition. We did note a different result when the experiment was performed in summer.[5]

Compared to the BASE values, the relaxation level (Fig. 1b) and thermal sensation of the whole body and foot under both conditions increased significantly during the foot immersion and recovery periods in this study ($P < 0.05$). There were no significant differences between the foot bath and the recovery period. However, thermal sensation decreased during the recovery period in comparison to the foot bath period, when we performed the experiment under the same conditions in summer.[5] We hypothesized the difference between mean skin temperature and foot temperature during the rest period influenced thermal sensation. In addition, we considered the possible effect of seasonal variation on physiological reactions to foot bathing.

Although SA is thought to be an indicator of stress via the sympathetic nervous system,[2, 3] we did not find a correlation between SA activity and relaxation level. These data suggest the need to investigate the validity of using SA activity, determined by a simple assay, for local stimulation. Therefore, SA activity with simple assay may not be an appropriate biological marker of stress.

Under the tested conditions, a relaxing effect was provided at an environmental temperature around 20 ˚C and water temperatures of 40 ˚C and 45 ˚C in winter. We considered the possible effect of body temperature during rest, and seasonal variation on the physiological reaction to foot bathing.

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The authors declare no conflict of interest.

REFERENCES

1 Roberts MF, Wenger CB, Stolwijk JA, Nadel ER. Skin blood flow and sweating changes following exercise training and heat acclimation. J Appl Physiol. 1977;43:133-7. PMID: 893254.
2 Speirs RL, Herring J, Cooper WD, Hardy CC, Hind CR. The influence of sympathetic activity and isoprenaline on the secretion of amylase from the human parotid gland. Arch Oral Biol. 1974;19:747-52. PMID: 4533726.
3 Yamaguchi M, Hanawa N, Yoshida H. Evaluation of a novel monitor for the sympathetic nervous system using salivary amylase activity. Seitai Ikogaku. 2007;45:161-8. Japanese with English abstract.
4 Nishimura M, Onodera S. [Relaxative effects of supine floating on heart rate, blood pressure and cardiac autonomic nervous system activity]. Uchu Koku Kankyo Igaku. 2000;37:49-56. Japanese. PMID: 12715823.
5 Nishimurara M, Kato T, Onodera S. Effects of water temperature and environmental temperature during foot bath. In: Biolo G, local organizer. Joint Meeting of the 31st Annual International Society for Gravitational Physiology Meeting, 11th European Space Agency Life Sciences Symposium, 5th Italian Society for Space Biomedicene and Biotechnology Symposium, European Low Gravity Research Association Sympodium program and abstract book; 2002 June 13–18; Trieste, Italy. Noordwijk: The Joint Meeting; 2002. p. 54.