Title page

Title: Skin Temperature Changes During a Footbath in Patient who had a Stroke with Sensory Impairment

Short running title: Skin Temperature Changes by a Footbath

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Abstract

Aim: The objectives of this study were to examine skin temperature changes on the unaffected and affected sides as well as changes in perceived temperature and comfort during a footbath in patients who had a stroke with sensory impairment.

Methods: The study used a quasi-experimental design in which the results of intervention for patient who had a stroke and healthy adults were compared. The subjects were 20 patients who had a stroke with sensory impairment and 20 healthy adults.

Results: Before the footbath, the skin temperature of the dorsum of the foot on the affected side of the patient who had a stroke was lower than that of the foot on the unaffected side. Five minutes after the start of the footbath, however, the relationship reversed, with the skin temperature on the affected side increasing in parallel with the water temperature. After the footbath, the dorsum skin temperature on the affected side was again lower than that on the unaffected side. In healthy adults, a difference was found in dorsum skin temperature between the left and right feet. In contrast to patient who had a stroke, no reversal of the sides was found with the lower and higher temperature.

Conclusions: Unlike in the healthy adults, the skin temperature of the patients who had a stroke with sensory impairment was susceptible to changes in the external environment. However, no significant changes in the physiological indices were seen, while perceived temperature and comfort remained at high levels after the footbath.

key words: footbath, sensory impairment, skin temperature, patient who had a stroke

INTRODUCTION

Patients who had a stroke with pain and numbness have found that the symptoms are alleviated by warming the body (Toki et al., 2007). The footbath is a well known nursing intervention for hygienic care and insomnia (Hattori et al., 2003; Liao et al., 2013; Nakayama, Kobayashi, & Takiuti, 2004; Sung & Tochihara, 2000). While the compress is the main treatment for pain relief, investigations regarding footbath effects include reports that it has no adverse effect on the circulatory system and that the skin temperature of the dorsum of the foot reaches high levels after 10 min in healthy, young individuals (Genta, 1979; Uebaba & Hooxu, 2004; Saino, 2012). Others have reported that the footbath has an effect on relaxation (Miyazato & Matsukawa, 2010; Saeki, 2000) and in controlling spasticity after stroke (Matsumoto et al., 2010).

At the same time, the use of the footbath for patients who had a stroke with sensory impairment or hemiplegia has been said to carry risks, including moderate temperature burns due to decreased sensation. However, only a few treatment reports found this, such as those by Morino, Oota, Fujimori, Sishido, & Kaneko (2002) and Kinoshita (2007). The skin temperature changes in the extremities on the affected and unaffected sides, and their extent, have not been elucidated. Moreover, the subjects in previous studies have been predominantly young. The studies have not included subjects who are middle-aged and elderly, and therefore more susceptible, or patients who had a stroke. It is therefore unclear whether the same conclusions can be drawn for patients who had a stroke with sensory impairment as for healthy individuals.

In order to obtain basic information on the performance of footbaths as a safe form of palliative care in patients who had a stroke with pain and numbness, we examined skin

temperature changes and perceived temperature and comfort when patients who had a stroke with sensory impairment receive a footbath.

Study objectives

The objectives of this study were: to compare skin temperature changes on both of the lower legs; to record subjective evaluations and physiological indices during a footbath; and to compare the differences between patients who had a stroke with sensory impairment and healthy adults.

Definition of Terminology

In this study, the term "footbath" refers to immersing the lower legs in warm water at a prescribed temperature for a specified period of time, without washing the feet in order to limit the stimulation. In addition, “sensitivity to cold” refers to as conditions that one always and unconsciously feels coldness on one’s hands and feet, tips of limbs, femoral and lumbar.

METHODS

Study design

The study had a quasi-experimental design, in which the results of intervention for patients who had a stroke and healthy adults were compared. The study was conducted after receiving approval from the ethical review board (ERB) of the Baika Women's University (10-18) and the ERBs of the hospitals that the subjects visited (Kyorin 10-08). The subjects signed informed consent forms after receiving written and oral explanations about the study, including the purpose of the study and publication of the

results.

Subjects

As shown in Table 1, the study subjects were 20 patients who had a stroke (14 men, 6 women) with sensory impairment who consented to participate in the study. The mean age (± SD) of the patients was 67.5 (± 10.15) years. The types of stroke were cerebral infarction in 14 patients, cerebral hemorrhage in 4, and cerebral infarction with cerebral hemorrhage in 2. An average of 38.9 months (a minimum of 2 to a maximum of 252 months) had passed after the stroke occurred. The impairment classification was sensory impairment for all 20 patients. Twelve patients were hemiplegic, 18 had amblyaphia and 2 had tactile anesthesia, but no paralgesia was found among these study subjects. The control group comprised 20 healthy adults (9 men, 11 women) who were included in the study because they had no cerebrovascular or metabolic disorder and no sensitivity to cold.

Study procedure and Footbath method

The study protocol is shown in Figure 1. The reference data used were: the heart rate, blood pressure, perceived temperature and comfort, skin temperature, and water temperature. These were determined while the subject sat resting for 10 min. The skin temperature was measured: before and immediately after the start of the footbath; at 5, 10, and 15 min after the start of the footbath; and at 5 and 10 min after its completion. The water temperature was measured: before and immediately after the start of the footbath; and at 5, 10, and 15 min after the start. Perceived temperature and comfort

were ascertained: before the footbath; at 10 and 15 min after the start of the footbath; and at 5 and 10 min after its completion.

With the subject sitting in a chair with a backrest or on the edge of a bed, both legs were immersed in the footbath bucket for 15 min after the initial measurements. Using a plastic footbath bucket (Ashiyu Senka, Inomata Kagaku Co., Osaka, Japan), 13 L of hot water (42.0°C) was prepared to immerse the lower leg up to approximately 18 cm from the sole of the foot. This was conducted while sitting with both legs immersed for 15 min. After the completion of the footbath, the water was wiped off with a towel, and finally, the subject sat and rested for 10 min with their feet covered with a towel.

This study was conducted in winter between December and March, within an air-conditioned room (a hospital room, outpatient examination room, or laboratory) keeping a temperature of 24.0 (± 0.89)°C and humidity of 37.0 (± 9.80)%.

Data collection method

Skin and water temperature:

A Compact Thermologger (AM-8000, Anritsu Meter Co., Ltd., Tokyo, Japan) was used to measure the dorsum of the foot and lower leg skin temperature while also measuring the water temperature during the footbath. For patients who had a stroke, affected side and unaffected side are separately measured. For healthy adults, two sides of the foot are separately measured: high pre-footbath and lower pre-footbath skin temperature. As shown in Figure 2, first the skin temperature probe on the dorsum of the foot was covered with a waterproof band-aid (BAND-AID® Water Block, Johnson & Johnson K.K., Tokyo, Japan) to prevent direct heat exposure. After this, 5 cm × 7 cm of

waterproof film (Nichiban Co., Ltd., Tokyo, Japan) was applied.

Perceived temperature and comfort:

As a subjective evaluation of the effects of the footbath, the perceived temperatures of the lower leg and the body as a whole were rated on a five-point scale. This scale was based on the evaluation method of Okada and Fukai. (2003), and was as follows: cold, 1 point; somewhat cold, 2 points; neither cold nor warm, 3 points; somewhat warm, 4 points; and warm, 5 points. Comfort was rated on a five-point scale as follows: uncomfortable, 1 point; somewhat uncomfortable, 2 points; neither comfortable nor uncomfortable, 3 points; somewhat comfortable, 4 points; and comfortable, 5 points.

Physiological indices:

Heart rate readings were monitored from 5 min before the footbath through to 10 min after its completion. Heart rate was continuously measured with a bipolar lead, using a memory heart rate monitor (LRR-03, GMS Co., Tokyo, Japan) with 3 lead wires connected to the chest electrodes. Blood pressure was measured before and after the start of the footbath using a digital sphygmomanometer (UA-767, A&D Co., Ltd., Tokyo, Japan).

Data analysis

The perceived temperature, comfort, and measured temperature were computed, and the average value of each period was obtained. Then the data was analyzed using Repeated Measures ANOVA followed by Dunnett’s test. For both groups, an analysis was made

using the t-test, based on: 1) the subjects' ages; 2) the skin temperatures of both feet; 3) perceived temperature and comfort; and 4) blood pressure readings before and after the footbath. For heart rate, following the analysis method of Goto, Tanaka, and Fujita (2012), the data for the first 2 min of each 5-min period were excluded in order to eliminate the effects of stimulation resulting from factors such as perceived temperature, as shown in Figure 1. Thus, the data for 3 min of each 5-min period were included in the analysis. The periods were designated as follows: 3 min before the start of the footbath - "before the footbath"; 2 to 5 min after the start of the footbath - "footbath 5 min"; 7 to 10 min after the start of the footbath - "footbath 10 min"; 12 to 15 min after the start of the footbath - "footbath 15 min"; 2 to 5 min after completion of the footbath - "5 min after completion"; and 7 to 10 min after completion - "10 min after completion."

For changes in heart rate, the mean rates for each 3 min were calculated for the high-frequency (HF) component (>0.15 Hz) and low-frequency (LF) component (0.04 to 0.15 Hz) by using a heart rate variability analysis program (MemCalc/Tarawa, GMS Co., Tokyo, Japan). Parasympathetic activity was evaluated by using the HF component, and sympathetic activity was evaluated using the ratio of the LF and HF components. The value obtained before the footbath was used as the reference value (1.00), the rate of change was determined from subsequent values, and Repeated Measures ANOVA and Dunnett's test were performed. The analysis was performed using the statistical software package SPSS 15.0J (SPSS Institute Japan KK, Tokyo, Japan) and a significance level of 0.5%.

RESULTS

Changes in skin and water temperature during the footbath

Water temperature

The water temperature for the patients who had a stroke gradually decreased, from 42.0 (± 0.07)°C before the footbath to 40.1 (± 0.47)°C at 10 min into the footbath and 39.4 (± 0.53)°C at 15 min into the footbath. Similar water temperature changes were seen with the healthy adults group, and the temperature remained at approximately 40.0°C throughout the footbath for both groups. No pronounced differences in water temperature were therefore seen between the groups, with both showing decreases in temperature immediately after the start of the footbath compared with before the footbath.

Skin temperature

As shown in Table 2, before the footbath, the skin temperature in the patients who had a stroke was slightly lower on the affected side than the unaffected side. Skin temperature on the dorsum of the foot was 31.8°C on the affected side and 32.7°C on the unaffected side. The skin temperature in this region was slightly higher on the affected side than on the unaffected side at 5 min into the footbath, and was the highest at 10 min into the footbath. During the footbath, the temperature of the affected side remained higher than the unaffected side. After the footbath, however, the temperature on the affected side decreased more rapidly than on the unaffected side, beginning from 5 min after footbath completion.

Meanwhile, the skin temperature of the lower leg on both sides also gradually

increased during the footbath. However, the temperature on the unaffected side was always higher than on the affected side.

For the control group of healthy adults, the skin temperature on the dorsum of the foot significantly increased compared with before the footbath (p =0.000), although the temperature differed between the left and right feet. However, unlike the affected side in the patients who had a stroke, in the control group the temperature of the leg which had the lower temperature before the footbath (low temperature side) did not become higher than that of the leg with the higher temperature before the footbath (high temperature side). For all 20 patients who had a stroke, the skin temperature on the dorsum of the foot on the affected side showed a reverse phenomenon during and after the footbath. In contrast, this did not happen in all 20 healthy adults.

Subjective evaluation of the footbath

Perceived temperature (warmth) and comfort

As shown in Table 3, the perceived temperature (warmth) of the lower legs when immersed in warm water was slightly higher than that of the whole body. In both groups, it was significantly higher at 10 min after the start of the footbath through to 10 min after completion, compared with before the footbath (p=0.000). Similarly, comfort was significantly higher at 10 min after the start of the footbath through to 10 min after completion, compared with before the footbath (p =0.000). No significant differences were found in perceived temperature or comfort between the two groups, yet the levels after footbath completion were slightly higher in the patients who had a stroke than in the healthy adults.

Changes in physiological indices during the footbath

Blood pressure

As shown in Table 4, no significant changes were found in systolic or diastolic blood pressure in the patients who had a stroke. In contrast, systolic and diastolic blood pressure significantly decreased in healthy adults.

Heart rate

Heart rate in the patients who had a stroke decreased from the start of the footbath at 82.2 until 10 min into the footbath, at 81.7 (p=0.846). It was higher, however, 15 min after the start of the footbath, at 82.2 (p=1.000) and 10 min after the footbath, at 83.5 (p=0.188). Yet, no significant change was found. In comparison, heart rate in the healthy adults gradually decreased after the start of the footbath, and was significantly lower at 5 min into the footbath, at 70.8 (p=0.015) to 10 min after footbath completion, at 70.3 (p=0.001), than it was before the footbath, at 72.3. (Table 4).

With regard to autonomic activity, as shown in Table 4, for the patients who had a stroke, the rate of change in the HF component, which indicates parasympathetic activity, gradually increased from the start of the footbath (1.00) to 15 min into the footbath, at 1.51 (p=0.530). The difference was not significant. The HF component in this group then decreased after footbath completion, but was higher at 10 min after completion, at 1.20 (p=0.943), than it was before the footbath. For the patients who had a stroke, the rate of change for LF/HF, which indicates sympathetic activity, was lower until 10 min into the footbath, at 0.93 (p=0.997), than at the start of the footbath, but

subsequently increased abruptly and was significantly higher (1.56) at 10 min after completion (p=0.033).

Meanwhile, in the healthy adults, the rate of change for the HF component was higher from the start of the footbath to 10 min after completion than it was before the footbath, at 1.13 (p=0.693). Yet, the rate of increase was higher than in the patients who had a stroke, and the rate of change was significantly higher (1.31) at 5 min after completion (p=0.044). Although no significant differences were found, the rate of change for LF/HF in the healthy adults decreased to 0.74 at 5 min into the footbath (p =0.077) and remained lower than before the footbath (0.86) through to 5 min after completion (p =0.585).

DISCUSSION

Skin temperature changes seen in patients who had a stroke

In the present study, skin temperature after immersion showed a change curve similar to the change curves seen in previous studies by Genta (1979) and Yatsuzuka, Oda and Ito (1999). In patients who had a stroke with sensory impairment or hemiplegia, sensory sensitivity to skin temperature is thought to be decreased in general. However, in the present study, skin temperature on the affected side of the dorsum of the foot immersed in warm water increased more rapidly than on the unaffected side, and rapidly decreased after removal from the warm water. This suggests that the surface temperature of the lower leg with sensory impairment is readily affected by the external environment. Patients with sensory impairment, in addition to being desensitized to temperature, may be susceptible to changes in body surface temperature resulting from

the influence of the external environment. In other words, skin temperature may be difficult to maintain in such patients.

Nakamura (2007) found that when measurements were performed with a probe immersed in warm water, the temperature sensor was susceptible to the effects of the water temperature, making it difficult to obtain an accurate skin temperature. In the present study, the site of the probe sensor was thoroughly waterproofed. A further difference is that this study attempts to find out the difference between the left and right legs. Unlike in Nakamura's study, the measurement value was not affected by water temperature, as this study focuses on comparing the gap between the left and right legs.

Left-right differences in skin temperature were also seen in the healthy adults in this study. Yet with this group, the side with the lower skin temperature was not affected by external temperature stimulation, as was seen in the patients who had a stroke. Both groups showed a similar phenomenon—a left-right difference in the skin temperature of the lower leg, with one side being cooler. However in the patients who had a stroke the cooler lower leg responded with greater sensitivity to the water temperature, while in the healthy adults the two sides responded similarly to it, and the whole-body response to the environmental temperature was different. This finding may indicate a response characteristic of patients who had a stroke with sensory impairment.

In studies, a constant water temperature is typically maintained using a constant-temperature bath, based on the need to control the environment. For the current investigation, however, the water temperature conditions used in the hospital room, outpatient examination room, and laboratory were uniformly established using the footbath bucket in order to obtain results under conditions that more closely

resembled the clinical setting. The data from this study showed that with a water temperature of 42.0°C, and under air conditioning during winter, the skin temperature peaked at 10 min, as in previous studies. With the water temperature maintained at 40.0°C, skin temperature held at 39.4°C at 15 min, when the footbath was completed.

Relationship between subjective evaluations and physiological indices

Referring to the study results of Genta (1979), a water temperature of 42.0°C was selected for the present study. The subjects in Genta's study said that this temperature was "not too hot" for a footbath during winter (December to March). Miyashita and Saeki (2000) found that a relaxation effect resulted from a footbath with a water temperature of 40.0°C, and Uebaba and Xu (2004) found that a temperature of 42.0°C increased arousal. The present study compared subjective evaluations of perceived temperature and comfort with physiological indices of blood pressure and heart rate. The patients who had a stroke continued to experience warmth and comfort after the footbath was completed, yet no change was seen in heart rate over time and in blood pressure after the footbath compared with before. Miwa et al. (2007) reported that with an outdoor footbath that used a hot spring, heart rate in patients with hemiplegia increased from the time 18 min after the start of the footbath to 1 min after its completion, and subsequently decreased. These results differ from those of the present study; heart rate initially decreased with the start of the footbath, began to increase at 15 min into the footbath, and remained at an increased level after the footbath was completed. The differences between these two studies may be explained by differences in the study environments. Specifically, the temperature of the environment in the study

by Miwa et al. (2007), in which a 20-minute outdoor footbath at 43.6°C, in an ambient temperature of 19.8°C, likely had a direct effect. Since the conditions in the present study differed from the outdoor footbath, the findings in the present study that footbaths are a relatively safe method of bathing that does not alter the blood pressure of patients who had a stroke can be viewed as being in agreement with Miwa et al (2007). In a study of healthy young men (mean age 21.3 years) that used a water temperature of 40.0°C in consideration of comfort, Kaneko, Kumagai, Ogata, Takemoto and Yamamoto (2009) concluded that footbaths stimulate parasympathetic activity and inhibit sympathetic activity. Xu and Uebaba (2003) concluded that a 30-min footbath showed a similar change in the circulation system and autonomic nervous system to a full bath and suggested limiting the length of footbath according to the water temperature; 15 minutes at 40℃ and 10 minutes at 42℃ are appropriate. These conclusions were based on findings of significant decreases in heart rate and blood pressure and significant increases in the HF component after a footbath. In the present study, trends toward stimulation of parasympathetic activity and, until 10 min into the footbath, inhibition of sympathetic activity were seen, yet they are insignificant. Conversely, from 15 min onward, sympathetic activity increased. Compared to healthy adults who retained lower sympathetic activity, this result shows a significant difference. This could be because the subject was sitting in the same posture throughout the experiment. In the healthy adults, stimulation of parasympathetic activity and inhibition of sympathetic activity were more sustained than in the patients who had a stroke, based on 1) the decrease in heart rate immediately after the start of the footbath; 2) the decreases in blood pressure; 3) the increase in HF; and 4) the decrease in LF/HF after the footbath. These changes

emerged during the footbaths and were similar to the results of Kaneko et al., This indicates that, among healthy adults, physical responses are roughly similar regardless of the age group.

The findings described above also show that, regardless of whether the individual was a patient who had a stroke or a healthy adult, a footbath resulted in feelings of warmth and comfort as well as increasing parasympathetic activity and inhibiting sympathetic activity during the footbath. Liao et al (2005) conducted a footbath experiment in the elderly (ages 63-73 years) in order to examine the distal-proximal skin temperature gradient (DPG) that affects sleep induction and concluded that DPG significantly increased at 10 minutes into footbath and that the effect of the footbath continued for 10 minutes after the footbath. Although a 15-min footbath increased sympathetic activity in patients who had a stroke, its subjective effects were sustained for 10 min after the footbath. These results indicate that, as Liao et al (2005) indicated, the comfort level remained in accordance with the increase of DPG.

Limitations of the study

This study has following limitations; 1) the controlled group has an age gap from the patient group because of the selection process which selected middle-aged adults without brain circulation disorder, metabolic disorder and sensitivity to cold; 2) the subject of study does not have similar levels of sensory impairment; and 3) the onset ages of 20 patients who had a stroke vary. For these reasons, it is unclear what aspects are affected by age, severity of numbness and sensory impairment (torpor, analgesia and hypersensitivity) and onset age.

CONCLUSION

The skin temperature changes from a footbath were compared between the affected and unaffected sides of patients who had a stroke, and with healthy adults. Subjective evaluations and physiological indices were also recorded. The results showed the following:

1. A left-right difference was found in the skin temperature for both patients who had a stroke and healthy adults

2. Skin temperature on the affected side in patients who had a stroke was higher than on the unaffected side during the footbath, and the skin temperature on the affected side was lower than on the unaffected side after completion of the footbath.

3. Skin temperature in healthy adults did not increase more on the low-temperature side than on the high-temperature side as a result of the footbath, although there was a left-right difference.

4. The footbath significantly increased perceived temperature (warmth) and comfort in both patients who had a stroke and healthy adults, and the increases continued after the footbath was completed.

5. The changes seen in the physiological indices were significant decreases in blood pressure and heart rate in healthy adults. Yet no significant changes in the physiological indices were seen in the patients who had a stroke.

6. Changes in autonomic activity that supported the subjective evaluations continued after the footbath in the healthy adults, but did not continue in the patients who had a stroke.

The above findings reveal that a footbath provides warmth and comfort for both

patients who had a stroke and healthy adults. Meanwhile, the findings imply that changes in the outer environment affect skin temperature of patients who had a stroke with sensory impairment more easily than that of healthy adults. This implies the risk of cold injury, as well as the previously known risk of thermal injury, on the side of foot with sensory impairment. Meticulous attention should therefore be given to nursing care.

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