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ORIGINAL ARTICLE

Effects of a warm hand bath on the blood flow in the shoulder, skin and deep body temperature, autonomic nervous activity, and subjective comfort in healthy women: An experimental cross-over trial

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Abstract

Aim: The present study was conducted in order to clarify the effects of a warm hand bath at 40°C for 10 min on the blood flow in the shoulder, skin and deep body temperature, autonomic nervous activity, and subjective comfort in healthy women.

Methods: The study's participants were 40 healthy adult women who were randomly assigned to either a structured hand bath first and no hand bath second (Group A) or to no hand bath first and a hand bath second (Group B). The blood flow in the shoulder, skin and deep body temperature, autonomic nervous activity, and subjective comfort then were recorded in all the participants.

Results: A repeated-measures ANOVA revealed no significant difference in the blood flow in the right shoulder or deep body temperature between groups. The skin temperature of the hands, forearms, and arms was significantly increased, but not of the face and upper back. The skin temperature of the forearms was maintained at 0.5°C–1°C higher for 30 min in the hand bath group, compared with the no hand bath group. The hand bath group had a significantly higher heart rate while bathing and a significantly lower parasympathetic nerve activity level during bathing. No significant difference was seen in the sympathetic activity level between groups. The hand bath group had a significantly higher subjective comfort level.

Conclusion: Hand baths can improve the level of subjective comfort and increase the heart rate and might affect autonomic nervous activity. The skin temperature of the forearms was maintained for 30 min in the hand bath group.

Key words: blood flow, comfort, heart rate, parasympathetic nervous system, skin temperature.

INTRODUCTION

Hand baths are an aspect of hygiene management in nursing care that involve filling a basin with warm water, soaking patients' hands, and removing the dirt and grime by using hand soap. Patients with contracted fingers find it particularly complicated to wash their hands (Tosti, Thoder, & Ilyas, 2013). However, if suitable hygiene conditions are not maintained, sebum can accumulate and an increased rate of a foul odor (Kuhn Timby, 2017). Hand baths therefore are considered to be an important aspect of hygiene management, in terms of caring for the patients' hands and enhancing their feelings of refreshment.

The warm water (38–41°C) that is used in hand baths stimulates the thermoreceptors in the skin (Hall, 2015a) and provides comfort and relaxation to the patient (Cal,

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Cakiroglu, Kurt, Hartiningsih, & Suryani, 2016; Saeki, 2000). In a previous study that investigated the implementation of hand baths in a Japanese hospital, >90% of the 229 nurses recognized their necessity, but the number of nurses that actually provided hand baths as part of their care was ≤18% (Miyashita & Yano, 2008). These findings suggest that presently, hand baths are not actively provided to patients. One of the reasons for this might be that the physiological effects of thermal stimulation, owing to hand baths, have not been clarified.

However, footbaths have been provided as part of nursing care by using warm water. Although footbaths were originally provided for hygiene management, they were found to suppress sympathetic nervous activity and activate parasympathetic nervous activity (Yamamoto, Aso, Nagata, Kasugai, & Maeda, 2008). Numerous studies have been conducted on footbaths and their association with sleep (Liao *et al.*, 2013; Seyyedrasooli, Valizadeh, Zamanzadeh, Nasiri, & Kalantri, 2013; Sung & Tochihara, 2000) and autonomic nervous activity, which can be used to assess relaxation (Saeki, 2000; Yamamoto *et al.*, 2008).

In a previous experimental study, local heating that was induced by a hand bath was found to affect the blood velocity in arteries supplying the skin of the hand and fingers (Bergersen, Eriksen, & Wales, 1995). The general rise that was seen in the blood velocity of the heated hand was considered to be the likely result of dilation of the ordinary arterioles of the skin because the spontaneous fluctuations in the blood velocity were assumed to be caused by synchronous vasomotor activity of the arteriovenous anastomoses that remained unchanged. Although some studies have investigated changes in the finger blood flow (BF), owing to thermal stimulation (Nagasaka, Cabanac, Hirata, & Nunomura, 1986), few have been conducted on the psychological effects of hand baths and none has comprehensively examined the physiological effects, such as those on the BF, body temperature, and autonomic nervous activity. Furthermore, the duration and maintenance of such physiological effects have not been verified. Hand baths are an aspect of nursing care that can be carried out easily for the purposes of hygiene and relaxation of patients; therefore, it is necessary to accumulate evidence that can clarify their physiological and psychological effects, and if appropriate, to promote their proactive implementation. This study thus aimed to clarify the effects of a warm hand bath on the BF, skin and deep body temperature, autonomic nervous activity, and subjective comfort in healthy Japanese women.

METHODS

Study design

An experimental cross-over design was used. The participants were assigned randomly to two groups: a structured hand bath first and no hand bath second (Group A) or no hand bath first and a hand bath second (Group B). The experimental protocol was set as resting for 20 min before the experiment, 10 min between conditions, and 90 min after the hand bath (Fig. 1).

Participants

The study's participants were healthy adult Japanese women who were aged ≥20 years. The sample size was calculated based on the heart rate (HRT) resulting from autonomic nervous activity, which was the primary outcome. Prior data indicated that differences in the mean

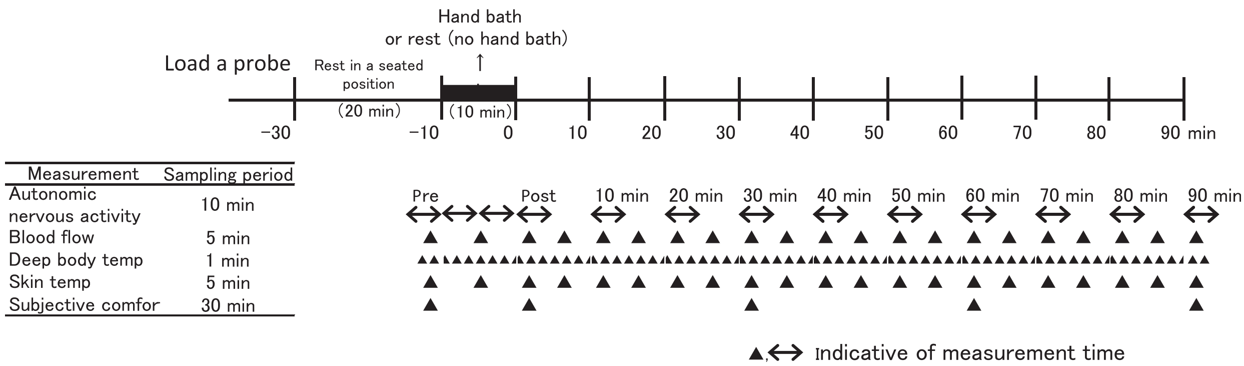

Figure 1 Experimental protocol. The autonomic nervous activity was sampled every 5 min at the beginning and every 10 min after the hand baths. temp, Temperature.

response of matched pairs are normally distributed with a standard deviation (SD) of 2.3 (Miyazato & Matsukawa, 2010). If the true difference in the mean response of matched pairs was 1, then 43 pairs of participants need to be studied to be able to reject the null hypothesis that the response difference is zero with a probability (power) of 0.8. The type I error probability that is associated with the test of this null hypothesis is 0.05. Therefore, the researchers recruited participants targeting 50 samples. Outlines of the present study were posted to bulletin boards at University A and 264 healthy female participants who were aged 20–29 years were recruited. Healthy adult women who were aged between 20 and 29 years were chosen as the study participants because the aim was to obtain data from participants with limited historical and environmental exposure factors and to unify the experimental conditions as much as possible. After excluding those who had internal medication affecting the autonomic nerves, 49 women were further assessed for eligibility. Figure 2 shows the flow of the participants through the trial. Among these 49 women, another seven were excluded: two who declined to participate, one who was >30 years of age, and four who had a Body Mass Index (BMI) of >25. The study was explained to the participants as follows: (i) get adequate sleep before the experiment; (ii) do not engage in intense exercising, eating, drinking, or smoking 2 h before the experiment (to avoid effects on the autonomic nervous activity); and (iii) do not participate in the experiment during menstruation.

Ethical considerations

This study was carried out in accordance with the Declaration of Helsinki and was approved by the Independent Ethics Committee at Akita University Graduate School of Medicine, Akita, Japan. Before starting the experiment, the protocol and procedures were explained to all the participants and written informed consent was obtained. All personal information was kept strictly confidential.

Measures

Characteristics of the participants

All the participants provided the following information regarding their background characteristics: age, history of smoking and drinking, regular exercise habits, symptoms of premenstrual syndrome (e.g. mood swings, tender breasts etc.), and prevalence of constipation, which affects autonomic nervous activity.

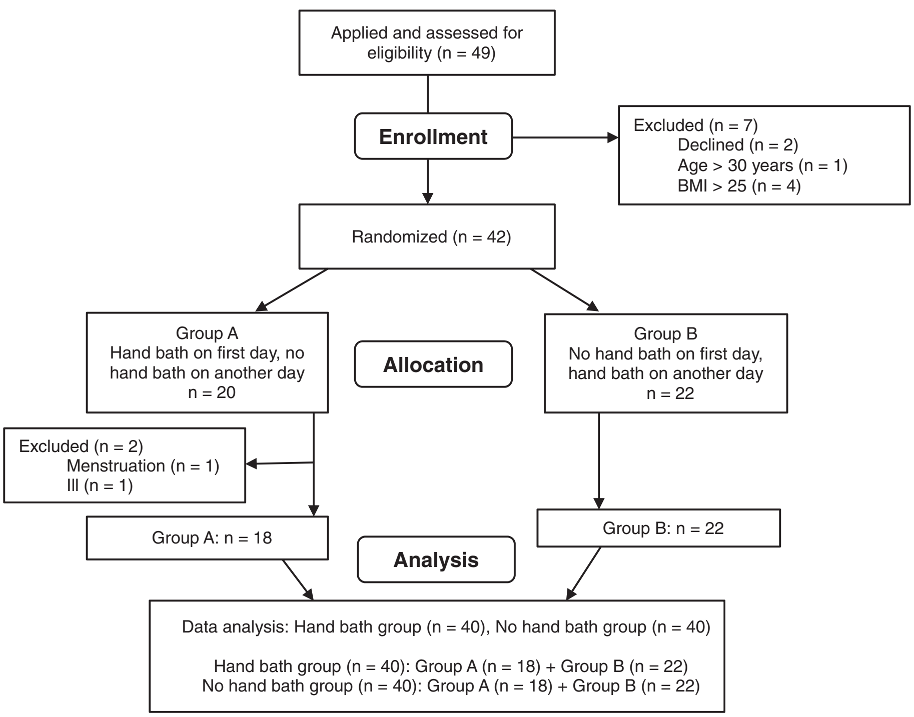

Figure 2 Flow diagram of the present study.

Blood flow in the shoulder

The BF in the shoulder was measured to investigate whether thermal stimulation from a hand bath would be transmitted through the arm to the shoulder by using an ultrasonic bidirectional BF meter (Smartdop 45; Hadeco, Kanagawa, Japan), based on photoplethysmography (PPG), which is the measurement of the BF, or blood pressure, by optical means and involves the measurement of changes in the transmission or scattering of light that is created by the BF in a specific part of the body. As shown on the right side of Figure 3, probes were attached to the center of the left and right trapezius muscle middle fibers, with reference to a prior study (Hagblad *et al.*, 2010). The BF was sampled every 5 min.

Skin temperature

A thermographic imager (Thermo Gear G120EX; Nippon Avionics Company, Ltd., Tokyo, Japan) with a measurement range of –40 to +1500°C, an accuracy of ±2°C or 2% of the measurement, an infrared spectral band from 8–14 μm, and a resolution of 0.04°C at 30°C was used to measure the skin temperature in the present study. The temperature in the laboratory was kept constant. Thermograms were recorded after the participants were acclimatized to the room conditions for 20–30 min. The skin temperature measurement range was set at 27–41°C and sampled every 5 min.

Based on the main body regions of interest for skin temperature measurements that have been used in a prior study (Marins *et al.*, 2014), the left and right sides of the hand, forearm, upper arm, chest, face, and upper back were analyzed. The mean skin temperatures from a total of 15 regions of interest were recorded by using the InfReC Analyzer NS9500 Standard (v. 2.6; Nippon Avionics Company, Ltd.). The rectangle-shaped regions of interest were determined by anatomical landmarks as follows: (i) "hand," the junction between the third metacarpal, third proximal phalanx, and ulnar styloid process (A, B, I, and J; Fig. 3); (ii) "forearm," the distal forearm and cubital fossa (C, D, K, and L; Fig. 3); (iii) "arm," the cubital fossa and axillary line (E, F, M, and N; Fig. 3); (iv) "chest (upper back)," from the center to below the right and left clavicle (G and O; Fig. 3); and (v) "face," from the eyes to the chin (H; Fig. 3).

Deep body temperature

A deep body thermometer (CoreTemp CM-210; Terumo Corporation, Tokyo, Japan) was used to examine the effect of a warm hand bath on the deep body temperature. This instrument measures the deep body temperature by using a zero-heat-flow method, with a measurement range of 0–50°C; it is accurate to within ±0.1°C.

The deep forehead temperature has been correlated strongly with changes in the temperature of the pulmonary artery (Lees, Kim, & Macnamara, 1980) and the deep abdominal temperature was correlated with changes in the rectal temperature (Tsuji *et al.*, 1976).

It was necessary to take a thermographic image from the face to the hand; thus, it was chosen to measure the deep abdominal temperature. A probe was attached ~5 cm under the epigastric region and the deep abdominal temperature was sampled every 1 min.

Autonomic nervous activity

The autonomic nervous activity was analyzed based on the heart rate variability (HRV) according to time- and

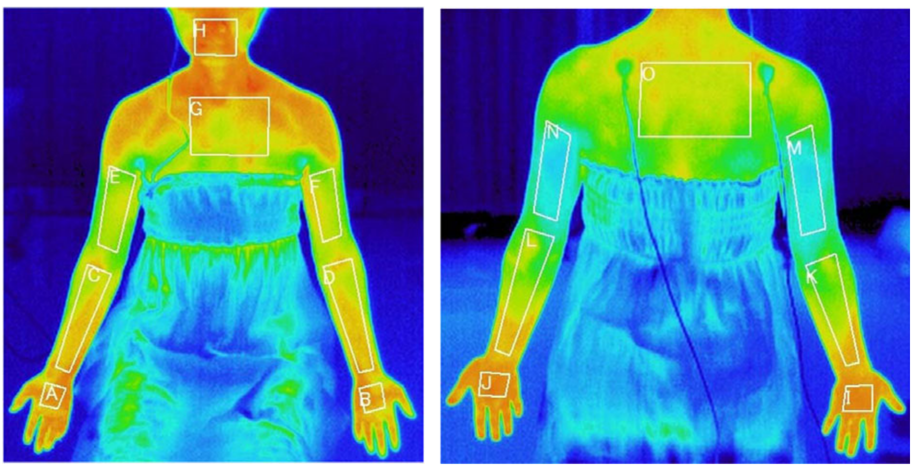

Figure 3 The 15 body regions of interest that were examined in the present study (A–O). Left image, ventral side; right image, dorsal side.

frequency-domain analyses. The HRT, the SD of the normal-to-normal (NN) interval (SDNN), and the root-mean-square of successive differences of the NN interval (RMSSD) were adopted in the time-domain analysis. The SDNN is strongly correlated with overall fluctuations, the RMSSD is associated with parasympathetic nervous activity, and reductions in the SDNN and RMSSD are interpreted as decreases in parasympathetic activity (Task Force of the European Society of Cardiology, the North American Society of Pacing Electrophysiology, 1996). In the frequency-domain analysis, a high frequency (HF) component, with a frequency band of 0.15–0.4 Hz, and a low frequency (LF) component, with a frequency band of 0.04–0.15 Hz, were used. The HF reflects the parasympathetic nerve tone that is caused by natural respiration and the ratio of the LF to the HF (LF/HF ratio) indicates the balance between the sympathetic and parasympathetic tones (Lehrer & Vaschillo, 2003).

In the present study, the HRV was examined by using a heart rhythm scanner (Heart Rhythm Scanner PE; Biocom Technologies, Poulsbo, WA, USA). The PPG data were recorded by using a pulse wave sensor (Biocom HRM-02; Biocom Technologies) that was clipped to the right earlobe. The HRV was measured for 5 min for each participant. The HRT, SDNN, RMSSD, HF, and LF/HF were sampled every 5 min before and during, and every 10 min after, the hand bath.

Subjective comfort

Three items, "Feels good," "Arm-to-shoulder comfort," and "Whole body comfort" were established by using a 10 cm visual analog scale (VAS), with high values indicating high comfort. The VAS was sampled every 30 min.

Hand bath intervention and procedures

The participants were given a warm hand bath (water temperature: 40°C) for 10 min. Their hands and forearms were immersed up to 3 cm above the radial styloid process without massaging. A hand bathtub (ASONE; THERMO MAX TM-2, Osaka, Japan) with a thermostat kept the water temperature constant. The participants were given a hand bath while resting in a seated position. After the hand bath, excess water on the skin was quickly removed by using a towel.

The study period was from January to March, 2016, in Japan. The laboratory environment had a constant room temperature of 26.4 ±0.9°C and a relative humidity of 20.2 ±4.3%. All the participants wore a strapless cotton gauze dress and half-pants, as can be seen in Figure 3. The intervention was carried out at least 2 h after a meal to avoid the effects of eating on the autonomic nervous activity.

Statistical analysis

First, the BF, skin and deep body temperature, autonomic nervous activity, and VAS scores were investigated by using the Kolmogorov–Smirnov test in order to confirm the normality of the data. The RMSSD, HF, and LF/HF were converted to natural logarithms. A two-way repeated-measures ANOVA was used to determine the effects of the hand bath. The Bonferroni method was used for post hoc comparisons between the hand bath and no hand bath groups. Each test was considered to be a separate analysis, with significance set at $P < 0.05$. To extract the factors that influenced the parasympathetic nervous activity in the hand bath group, a forced-entry multiple regression analysis was carried out with parasympathetic nervous activity as the purpose variable and the target attributes as the explanatory variables. The data for each variable are presented as the mean ±SD. SPSS (v. 22J; SPSS Institute Japan, Tokyo, Japan) was used for all the data analyses.

RESULTS

Randomization and the participants

In total, 42 participants were assigned randomly to either the structured hand bath first and no hand bath second (Group A) or no hand bath first and a hand bath second (Group B) in a cross-over trial (Fig. 2). Two participants, one who was menstruating and another who was ill, were excluded from Group A, leaving 40 participants each in the hand bath and no hand bath groups.

Demographic characteristics

The mean age of the participants was 20.9 ±0.8 years (range: 20–23 years). The characteristics of the participants are shown in Table 1. In total, 23 and 13 women had symptoms of premenstrual syndrome and constipation, respectively.

Blood flow in the shoulder

As shown in Table 2, only the main effect of time on BF in the left shoulder was statistically significant ($P < 0.05$). The left BF in the hand bath group increased significantly immediately after the hand bath, compared with the no hand bath group (0.91 ±0.61 mV/V *vs*

Table 1 Demographic characteristics of the participants (n = 40)

Characteristic	N	%
History of smoking		
Yes	0	0.0
No	40	100.0
History of drinking		
Yes	13	32.5
No	27	67.5
Regular exercise		
Yes	9	22.5
No	31	77.5
Premenstrual syndrome		
Yes	23	57.5
No	17	42.5
Constipation		
Yes	13	32.5
No	27	67.5

0.54 ±0.23 mV/V; $P < 0.05$); however, the increase in BF was temporary.

Skin temperature

An example of the thermographic images that were taken of the regions of interest is shown in Figure 4. Heat transfer was observed at the root of the cephalic, ulnar, and axillary veins. As shown in Table 2, the main effects of time on 14 regions of interest other than the upper back were statistically significant ($P = 0.000$). The main effect of the hand bath intervention on the dorsal right forearm was statistically significant ($P < 0.05$). The interaction effects of time × the intervention on 12 regions of interest other than the right and left dorsal arm and upper back were statistically significant ($P = 0.000$~0.025). As shown in Tables 2 and 3, the skin temperature increased from the hand to the forearm, ventral arm, and chest after the hand bath intervention, but no significant difference was seen for the face, upper back, or dorsal arm. When examined in detail, the skin temperatures in the hand bath group were significantly higher immediately after bathing ($P < 0.001$), but no difference was seen after 5 min in the ventral hands. In the dorsal hands, a significant difference was seen at 20 min after the hand bath and the skin temperature was higher in the hand bath group. In the forearms, a significant difference was observed in the hand bath group up to 30 min after the hand bath, with skin temperatures increasing by ~0.5–1°C, compared with the no hand bath group. Significant differences were observed up to 15 min after the hand bath in the ventral, but not in the dorsal, arm.

Deep body temperature

The main effect of time on the deep body temperature was statistically significant ($P = 0.000$; Table 2), but not the main effect of the intervention and the interaction effect of time × the intervention. The deep body temperature temporarily increased by ~0.1°C during and after bathing in the hand bath group, but this increase was not statistically significant.

Autonomic nervous activity

The HRT was significantly higher in the hand bath group than in the no hand bath group (85.9 ±11.4 *vs* 80.3 ±10.2/min; $P = 0.031$; Table 4). In the hand bath group, the HRT returned to the standard value at ~30 min after the hand bath. The SDNN (36.9 ±10.4 *vs* 51.4 ±14.3 ms; $P = 0.000$), RMSSD (3.1 ±0.4 *vs* 3.4 ±0.4; $P = 0.002$), and HF (4.2 ±0.9 *vs* 4.6 ±0.7; $P = 0.042$) all were significantly lower in the hand bath than in the no hand bath group. In the hand bath group, the SDNN, RMSSD, and HF temporarily decreased during bathing, but returned to the standard value ~20 min after the hand bath. No significant difference was seen in the LF/HF during or after bathing.

Next, a forced-entry multiple regression analysis was conducted, adjusting for age, BMI, room temperature, and humidity, in order to extract the factors that might have caused the decreased parasympathetic nervous activity during bathing. No collinearity was detected. The objective variables were the SDNN, RMSSD, and HF and the explanatory variables were the VAS scores, premenstrual syndrome, and constipation. As a result, the RMSSD ($\beta = -0.70$, $P = 0.000$; Table 5) and HF ($\beta = -0.65$, $P = 0.000$; Table 5) was associated with constipation. A repeated-measures ANOVA then was carried out on the hand bath group, which was divided into a constipation group and a no constipation group. The RMSSD and HF were significantly higher in the no constipation, than in the constipation, group; these values were high not only during bathing, but also during the overall experimental time (Fig. 5).

Subjective comfort

The main effect of time, the main effect of the intervention, and the interaction effect of time × the intervention on the three items of the VAS were statistically significant (Table 2). In the hand bath group, the VAS

Table 2 Intervention effects on the physiological and subjective indices in the repeated-measures ANOVA

Variable	Main effect of time			Main effect of the intervention			Interaction effect		
	F	*P*	Partial η^2	F	*P*	Partial η^2	F	*P*	Partial η^2
Blood flow in the shoulder									
Right	1.734	0.142	0.093	1.008	0.329	0.056	0.453	0.795	0.026
Left	2.542	**0.011**	0.083	0.254	0.618	0.009	1.955	0.052	0.065
Skin temperature									
A: Ventral hand (R)	23.785	**0.000**	0.243	0.747	0.390	0.010	5.065	**0.000**	0.064
B: Ventral hand (L)	19.619	**0.000**	0.210	0.749	0.390	0.010	4.428	**0.000**	0.056
C: Ventral forearm (R)	67.169	**0.000**	0.476	2.887	0.094	0.038	39.001	**0.000**	0.345
D: Ventral forearm (L)	67.288	**0.000**	0.476	3.427	0.068	0.044	38.986	**0.000**	0.345
E: Ventral arm (R)	5.487	**0.000**	0.069	0.318	0.575	0.004	5.815	**0.000**	0.073
F: Ventral arm (L)	5.369	**0.000**	0.068	0.802	0.373	0.011	5.046	**0.000**	0.064
G: Chest	3.530	**0.000**	0.046	0.016	0.898	0.000	2.012	**0.019**	0.026
H: Face	13.694	**0.000**	0.160	0.246	0.622	0.003	1.938	**0.025**	0.026
I: Dorsal hand (R)	35.327	**0.000**	0.323	2.220	0.141	0.029	8.008	**0.000**	0.098
J: Dorsal hand (L)	35.277	**0.000**	0.323	1.851	0.178	0.024	9.954	**0.000**	0.119
K: Dorsal forearm (R)	72.129	**0.000**	0.497	6.226	**0.015**	0.079	35.729	**0.000**	0.329
L: Dorsal forearm (L)	44.026	**0.000**	0.373	1.560	0.216	0.021	19.509	**0.000**	0.209
M: Dorsal arm (R)	7.214	**0.000**	0.089	1.017	0.316	0.014	1.191	0.315	0.016
N: Dorsal arm (L)	7.963	**0.000**	0.097	0.257	0.613	0.003	1.565	0.196	0.021
O: Upper back	0.599	0.627	0.008	0.062	0.804	0.001	1.542	0.202	0.020
Deep body temperature in the abdomen	31.932	**0.000**	0.355	0.050	0.824	0.001	0.313	0.751	0.005
Autonomic nervous activity									
HRT (/min)	2.793	**0.032**	0.038	0.103	0.749	0.001	10.652	**0.000**	0.130
SDNN (ms)	15.366	**0.000**	0.178	0.272	0.603	0.004	4.297	**0.000**	0.057
RMSSD (Ln)	6.921	**0.000**	0.090	0.144	0.705	0.002	3.863	**0.001**	0.052
HF (Ln)	2.873	**0.006**	0.039	0.010	0.920	0.000	3.233	**0.003**	0.044
LF/HF (Ln)	10.146	**0.000**	0.125	0.019	0.892	0.000	0.924	0.504	0.013
Visual analog scale									
Feels good	29.003	**0.000**	0.282	11.030	**0.001**	0.130	25.591	**0.000**	0.257
Arm-to-shoulder comfort	30.269	**0.000**	0.293	7.091	**0.010**	0.890	24.117	**0.000**	0.248
Whole body comfort	23.419	**0.000**	0.243	8.821	**0.004**	0.108	18.055	**0.000**	0.198

HF, High frequency; HRT, heart rate; L, left; LF/HF, low frequency/high frequency; Ln, converted to natural logarithms; R, right; : RMSSD, root-mean-square of successive differences of the normal-to-normal interval; SDNN, standard deviation of the normal-to-normal interval. The bold values indicate those with significant differences.

scores were significantly higher at posthand bath, post30 min, and post60 min (Table 6).

DISCUSSION

Regarding the effect of the hand bath on the BF in the shoulder, no significant difference was seen between the two groups in the right shoulder; the BF in the hand bath group increased only in the left shoulder. However, this effect was temporary and immediately showed the same effect as those in the no hand bath group. In addition, no significant difference was seen between the two groups in the upper back skin temperature (region of interest O in Fig. 3). These results suggest that hand baths do not affect the BF in the trapezius muscle fibers or skin temperature. Regarding the cause of this lack of influence on the BF in the shoulder, it was considered that the temperature and time (at 40°C for 10 min) were insufficient. In addition, as the probe was applied to the center of the left and right trapezius muscle fibers, it was considered that the trapezius muscle could not accurately detect the surface BF because of the thickness of the muscle layer. According to the results of the thermographic imaging, heat transfer was observed at the root of the cephalic, ulnar, and axillary veins after a hand bath at 40°C for 10 min; therefore, future studies will need to verify changes in the BF in the forearm and upper arm.

In the present study, visual changes in the skin temperature were clarified for the first time by thermograms. In addition to the heat transfer route, as

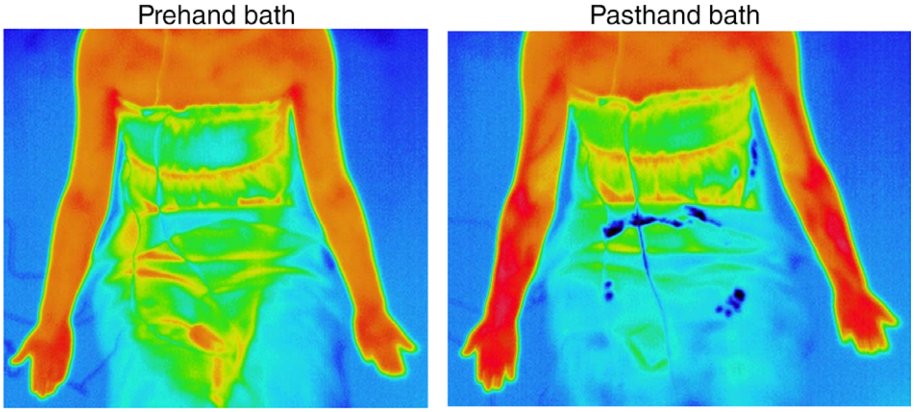

Figure 4 Skin temperature in the hand bath group, according to infrared thermograms. Heat transfer was observed at the root of the cephalic, ulnar, and axillary veins.

mentioned above, hand baths at 40°C for 10 min had no effect on the face and upper back skin temperatures. The temperatures were thought to have decreased immediately in the ventral hands after the hand bath because of heat radiation owing to vaporization. Another reason could be that the ventral hands often produce a large amount of sweat (Ohara & Ono, 1963). The skin temperature in the hand bath group increased significantly in the ventral arms, but no significant difference was seen in the skin temperature in the dorsal arms. This was thought to be related to the thick layer of subcutaneous fat on the posterior surface of the dorsal arms, which made the thermal stimulation that was transmitted through the vein unable to be detected by the thermograms. The skin temperature of the forearms was maintained at 0.5–1°C higher for 30 min in the hand bath group, compared with the no hand bath, group. The shoulders and arms of the participants in this study were exposed to room air when a picture was taken of the upper body for the infrared thermograms. Heat loss has been shown to be substantial when the skin is exposed to room air (Hall, 2015b), which could explain the substantial heat loss that was seen in the present study. As hand baths are an aspect of nursing care that are carried out on clothed patients, the heat retention effect by hand baths could be expected to be longer than the 30 min that was observed in this study. In addition, subjective comfort was maintained for ~60 min in the present study. From the above observations, it is thought that subjective comfort would continue in accordance with the warmth.

The results of this study also showed that a hand bath at 40°C for 10 min had no effect on the deep body temperature. Sleep is reportedly more difficult during periods of high body temperature (Tan *et al.*, 2003); therefore, the hand baths might be able to be carried out without disturbing a patient's sleep, even if given immediately before sleep onset. However, the deep body temperature could increase if hand bathing is conducted for >10 min. It will be necessary to consider how the duration of hand bathing affects the deep body temperature in a future study.

Regarding the autonomic nervous activity, the results in the present study were different from those in a previous study on footbaths. Footbaths suppress sympathetic nervous activity and activate parasympathetic nervous activity (Yamamoto *et al.*, 2008), but in the present study, the hand bath raised the HRT and temporarily reduced the parasympathetic nervous activity. As an increase in the HRT indicates the activation of sympathetic nerve activity, it seems that hand baths activate sympathetic nerve activity. In contrast, the SDNN, RMSSD, and HF, which indicate parasympathetic nervous activity, temporarily declined during the hand bath in the hand bath group. In one previous study, footbaths were shown to temporarily suppress parasympathetic nervous activity (Takemoto, Takahashi, Sasaki, Maruyama, & Yamamoto, 2007), but in another study, they were shown to activate parasympathetic activity (Saeki, 2000). The decline in parasympathetic activity during hand bathing might have been affected by attitude maintenance and oscillation of the thermostat when the hands were placed in the hand bathtub. In addition, temporary stimulation that was caused by placing the participants' hands in hot water (40°C) and exposing their shoulders to room air might have resulted in reduced parasympathetic activity. The multiple regression analysis that had been adjusted for age, BMI, room temperature, and humidity showed a significant relationship between the RMSSD, HF, and constipation. However, the repeated-measures ANOVA showed that the RMSSD and HF were significantly higher in the no constipation, than in the constipation, group; these remained high not only during the bathing,

Table 3 Comparison of the skin temperature between the hand bath and no hand bath groups

		Prehand bath			Posthand bath			Post5 min			Post10 min			Post15 min			Post20 min			Post25 min			Post30 min			Post35 min			Post40 min		
Variable	Group	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
A: Ventral hand (R)	H	34.9	1.1	NS	**36.6**	**0.5**	***	35.8	0.6	NS	35.7	0.6	NS	35.7	0.6	NS	35.6	0.7	NS	35.6	0.7	NS	35.5	0.8	NS	35.5	0.7	NS	35.5	0.7	NS
	N	34.8	1.1		**35.5**	**1.0**		35.5	1.0		35.4	0.9		35.5	1.0		35.3	0.9		35.4	1.0		35.3	1.0		35.3	1.1		35.3	1.0	
B: Ventral hand (L)	H	34.7	1.3	NS.	**36.5**	**0.5**	***	35.6	0.6	NS	35.6	0.7	NS	35.6	0.8	NS	35.5	0.8	NS	35.5	0.8	NS	35.5	0.8	NS	35.4	0.8	NS	35.4	0.8	NS
	N	34.7	1.3		**35.4**	**1.1**		35.4	1.1		35.3	1.1		35.4	1.1		35.2	1.0		35.3	1.1		35.2	1.0		35.2	1.1		35.2	1.0	
C: Ventral forearm (R)	H	34.3	0.8	NS	**36.3**	**0.6**	***	**35.7**	**0.6**	***	**35.4**	**0.5**	***	**35.3**	**0.5**	**	**35.1**	**0.6**	**	35.0	0.6	NS	35.0	0.6	NS	34.9	0.6	NS	34.9	0.6	NS
	N	34.4	0.8		**34.8**	**0.8**		**34.8**	**0.7**		**34.8**	**0.7**		**34.9**	**0.8**		**34.7**	**0.8**		34.7	0.7		34.7	0.7		34.7	0.7		34.7	0.7	
D: Ventral forearm (L)	H	34.2	0.9	NS	**36.2**	**0.6**	***	**35.5**	**0.6**	***	**35.3**	**0.5**	***	**35.1**	**0.6**	**	**35.0**	**0.6**	*	34.9	0.6	NS	**34.9**	**0.6**	*	34.8	0.6	NS	34.8	0.6	NS
	N	34.2	0.8		**34.7**	**0.8**		**34.7**	**0.7**		**34.7**	**0.7**		**34.6**	**0.8**		**34.6**	**0.7**		34.6	0.7		**34.6**	**0.7**		34.6	0.7		34.6	0.7	
E: Ventral arm (R)	H	33.9	0.6	NS	**34.6**	**0.8**	***	**34.3**	**0.7**	*	**34.3**	**0.7**	*	34.1	0.6	NS	34.1	0.7	NS	34.0	0.7	NS	34.0	0.6	NS	33.9	0.6	NS	33.9	0.7	NS
	N	34.0	0.6		**33.9**	**0.6**		**33.9**	**0.7**		**33.9**	**0.7**		33.8	0.7		33.9	0.7		33.8	0.7		33.9	0.6		33.8	0.7		33.8	0.7	
F: Ventral arm (L)	H	33.8	0.7	NS	**34.4**	**0.8**	***	**34.2**	**0.7**	*	**34.2**	**0.6**	**	**34.0**	**0.6**	*	34.0	0.7	NS	34.0	0.7	NS	33.9	0.6	NS	33.8	0.7	NS	33.9	0.6	NS
	N	33.9	0.6		**33.9**	**0.6**		**33.9**	**0.7**		**33.8**	**0.6**		**33.7**	**0.7**		33.8	0.7		33.7	0.7		33.8	0.6		33.7	0.7		33.7	0.6	
G: Chest	H	34.5	0.6	NS	**34.7**	**0.6**	*	34.6	0.7	NS	34.7	0.6	NS	34.5	0.6	NS	34.5	0.8	NS	34.6	0.5	NS	34.5	0.5	NS	34.4	0.5	NS	34.5	0.6	NS
	N	34.5	0.6		**34.4**	**0.5**		34.5	0.6		34.5	0.5		34.4	0.5		34.5	0.6		34.4	0.6		34.5	0.5		34.5	0.5		34.5	0.5	
H: Face	H	34.9	0.7	NS	35.6	0.7	NS	35.5	0.6	NS	35.5	0.6	NS	35.6	0.5	NS.	35.6	0.5	NS	35.5	0.5	NS	35.6	0.4	NS	35.5	0.6	NS	35.6	0.5	NS
	N	35.0	0.7		35.3	0.5		35.4	0.6		35.4	0.5		35.3	0.6		35.4	0.6		35.4	0.6		35.5	0.5		35.4	0.5		35.5	0.5	
I: Dorsal hand (R)	H	34.1	1.1	NS	**36.0**	**0.6**	***	**35.6**	**0.4**	***	**35.5**	**0.5**	**	**35.4**	**0.6**	*	**35.3**	**0.6**	*	35.2	0.6	NS	35.1	0.6	NS	35.1	0.7	NS	35.0	0.6	NS
	N	34.2	1.2		**34.9**	**0.9**		**34.9**	**0.9**		**34.9**	**0.8**		**35.0**	**0.9**		**34.8**	**0.9**		34.9	0.9		34.9	0.9		34.8	1.0		34.8	0.9	
J: Dorsal hand (L)	H	34.1	1.5	NS	**36.3**	**0.6**	***	**35.7**	**0.4**	***	**35.5**	**0.5**	**	**35.4**	**0.6**	*	**35.3**	**0.6**	*	35.2	0.6	NS	35.1	0.6	NS	35.1	0.7	NS	35.1	0.7	NS
	N	34.2	1.2		**35.0**	**1.0**		**35.0**	**1.0**		**35.0**	**1.0**		**35.0**	**1.0**		**34.9**	**1.0**		34.9	1.0		34.9	1.0		34.9	1.0		34.8	1.0	
K: Dorsal forearm (R)	H	33.9	0.5	NS	**35.1**	**0.8**	***	**34.7**	**0.5**	***	**34.4**	**0.5**	***	**34.3**	**0.5**	***	**34.2**	**0.6**	***	**34.1**	**0.5**	**	**34.0**	**0.5**	*	**33.9**	**0.5**	*	33.9	0.5	NS
	N	34.0	0.7		**33.8**	**0.6**		**33.8**	**0.6**		**33.8**	**0.6**		**33.7**	**0.7**		**33.6**	**0.7**		**33.6**	**0.6**		**33.6**	**0.7**		**33.6**	**0.7**		33.6	0.6	
L: Dorsal forearm (L)	H	33.8	0.6	NS	**34.7**	**0.7**	***	**34.4**	**0.6**	***	**34.2**	**0.6**	**	**34.2**	**0.6**	**	**34.1**	**0.6**	*	34.0	0.6	NS	34.0	0.6	NS	33.9	0.6	NS	33.8	0.6	NS
	N	34.0	0.7		**33.9**	**0.7**		**33.9**	**0.7**		**33.8**	**0.7**		**33.8**	**0.7**		**33.7**	**0.8**		33.7	0.7		33.8	0.7		33.7	0.7		33.7	0.8	
M: Dorsal arm (R)	H	32.9	1.0	NS	33.2	0.9	NS	33.2	0.8	NS.	33.1	0.9	NS	33.1	0.9	NS	33.0	0.9	NS	33.0	0.8	NS	33.0	0.8	NS	32.9	0.8	NS	32.9	0.8	NS
	N	32.7	1.0		32.9	0.8		32.9	0.7		32.8	0.8		32.8	0.8		32.8	0.9		32.8	0.8		32.8	0.8		32.8	0.8		32.8	0.8	
N: Dorsal arm (L)	H	32.9	0.9	NS	33.3	0.8	NS	33.2	0.8	NS	33.1	0.8	NS	33.1	0.8	NS	33.1	0.8	NS	33.0	0.8	NS	33.0	0.7	NS	33.0	0.7	NS	33.0	0.7	NS
	N	32.9	0.9		33.0	0.8		33.0	0.8		33.0	0.8		32.9	0.8		32.9	0.8		32.9	0.8		32.9	0.8		32.9	0.8		32.9	0.9	
O: Upper back	H	35.0	0.6	NS	34.8	0.9	NS	34.9	0.7	NS	35.0	0.6	NS	35.0	0.6	NS	35.0	0.6	NS	35.0	0.6	NS	35.0	0.5	NS	35.0	0.5	NS	35.0	0.5	NS
	N	35.0	0.6		35.1	0.5		35.1	0.5		35.0	0.6		35.1	0.6		35.0	0.6		35.0	0.6		35.0	0.6		35.0	0.6		35.0	0.6	

Data recorded after 45 min were omitted because no significant difference was observed between the hand bath and no hand bath groups. $^{*}P < 0.05$, $^{**}P < 0.01$, and $^{***}P < 0.001$, according to hand bath group (H) *vs* no hand bath group (N). L, Left; NS, non-significant; R, right; SD, standard deviation. The bold values indicate those with significant differences.

Table 4 Comparison of autonomic nervous activity between the hand bath and no hand bath groups

Variable	Group	Prehand bath			Hand bath 0–5 min			Hand bath 6–10 min			Posthand bath			Post10 min			Post20 min			Post30 min		
		Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
HRT	H	81.0	10.0	NS	83.6	10.6	NS	**85.9**	**11.4**	*	84.1	10.6	NS	82.2	10.7	NS	82.2	10.7	NS	81.4	10.7	NS
	N	81.0	10.4		79.9	10.9		**80.3**	**10.2**		80.5	10.6		80.6	11.7		81.2	11.6		81.4	11.1	
SDNN	H	44.7	13.5	NS	43.7	12.5	NS	**36.9**	**10.4**	***	56.7	14.9	NS	47.4	14.7	NS	51.9	17.3	NS	54.2	14.5	NS
	N	45.1	10.9		48.4	13.8		**51.4**	**14.3**		54.5	15.9		54.1	15.4		54.6	13.2		54.3	15.1	
RMSSD	H	3.3	0.4	NS	3.2	0.4	NS	**3.1**	**0.4**	**	3.4	0.4	NS	3.3	0.4	NS	3.4	0.5	NS	3.4	0.5	NS
(Ln)	N	3.3	0.4		3.4	0.4		**3.4**	**0.4**		3.4	0.4		3.5	0.5		3.4	0.4		3.4	0.4	
HF (Ln)	H	4.5	0.7	NS	4.4	0.8	NS	**4.2**	**0.9**	*	4.7	0.7	NS	4.5	0.8	NS	4.7	0.7	NS	4.7	0.8	NS
	N	4.5	0.7		4.7	0.7		**4.6**	**0.7**		4.7	0.8		4.8	0.7		4.6	0.6		4.6	0.7	
LF/HF	H	0.5	0.8	NS	0.4	0.9	NS	0.5	0.8	NS	0.7	0.7	NS	0.7	0.8	NS	0.8	0.8	NS	0.9	0.8	NS
(Ln)	N	0.6	0.7		0.5	0.7		0.6	0.8		0.8	0.7		0.7	0.8		0.7	0.7		0.9	0.7	

Data recorded after 40 min were omitted because no significant difference was observed between the hand bath group and the no hand bath group. $*P < .05$, $**P < .01$, and $***P < .001$ according to hand bath group (H) *vs* no hand bath group (N). HF, High frequency; HRT, heart rate; LF/HF, low frequency/high frequency; Ln, converted to natural logarithms; NS, non-significant; RMSSD, root-mean-square of successive differences of the normal-to-normal interval; SD, standard deviation; SDNN, standard deviation of the normal-to-normal interval. The bold values indicate those with significant differences.

but also during the overall experimental time (Fig. 5). From the above observations, constipation was shown to not be a factor that decreases parasympathetic nervous activity during bathing. The reason for the decline in parasympathetic nervous activity during bathing in the present study is considered to have been purely the influence of the hand bath. Although the level of parasympathetic nervous activity temporarily declined during hand bathing, it tended to rise immediately after bathing and returned to the standard value. This phenomenon was thought to be the mechanism that maintains homeostasis of the living body; that is, a mechanism that counteracts the decrease in parasympathetic nervous activity. Based on the above results, when considering that hand baths appear to activate sympathetic, and temporarily reduce parasympathetic, nervous activity, it might be favorable to incorporate hand baths into nursing care on patient awakening in the morning.

Based on the VAS scores, hand baths seemed to have provided subjective comfort and relaxation. This result was consistent with those reported in studies by Cal et al. (2016), Miwa *et al.* (2016), and Yamamoto *et al.* (2008), which focused on the comfortable feeling of the hand bath.

Hand baths raise the skin temperature from the hand to the chest, maintain the warmth in the arm for ~30 min, raise the HRT during hand bathing, and temporarily decrease parasympathetic nervous activity. From the above findings, hand baths appear to be effective for providing comfort and relaxation; in addition, hand baths seem to be an aspect of nursing care that can be safely and positively used to activate sympathetic nervous activity.

Limitations of the study

A few limitations must be noted. First, because this experiment was not conducted in an artificial climate, the low relative humidity during the research period might have affected the data and the fact that the experiment was conducted during the summer, when it was hot and humid, might have affected subjective comfort. Second, attitude maintenance and oscillation of the thermostat and exposure of the shoulder to room air when the hands were placed in the hand bathtub might have caused a decline in parasympathetic nervous activity during hand bathing. Third, because this was a cross-over trial, there might have been a bias that originated from the carry-over effect. Therefore, in order to obtain more generalizable outcomes in future studies,

Table 5 Multiple regression analysis of the relationship between the indicators of parasympathetic nerve activity and the attributes, adjusted for covariates

	β-value for parasympathetic nerve activity					
	RMSSD			HF		
Variable	β-value (SE)	95% Cl	P-value	β-value (SE)	95% Cl	P-value
Visual analog scale						
Feels good	0.20 (0.01)	−0.01 to 0.02	0.301	0.21 (0.01)	−0.01 to 0.04	0.316
Arm-to-shoulder comfort	−0.18 (0.01)	−0.02 to 0.01	0.566	−0.06 (0.02)	−0.03 to 0.03	0.856
Whole body comfort	0.15 (0.01)	−0.01 to 0.02	0.666	0.14 (0.02)	−0.03 to 0.05	0.676
Premenstrual syndrome	−0.19 (0.14)	−0.44 to 0.12	0.251	−0.23 (0.29)	−0.99 to 0.19	0.177
Constipation	**−0.70 (0.14)**	**−0.91 to − 0.32**	**0.000**	**−0.65 (0.30)**	**−1.8 to − 0.58**	**0.000**

Adjusted for age, Body Mass Index, room temperature, and humidity. CI, Confidence interval; HF, high frequency; RMSSD, root-mean-square of successive differences of the normal-to-normal interval; SE, standard error. The bold values indicate those with significant differences.

further research should be conducted in rooms with an artificial climate and the data should be collected without using a thermostat.

CONCLUSION

To the authors' knowledge, this is the first study to comprehensively investigate the effects of a hand bath at 40°C for 10 min on the BF, skin and deep body temperature, autonomic nervous activity, and subjective comfort. Hand baths increase the subjective comfort and HRT and might affect autonomic nervous activity. The skin temperature of the forearms was maintained at 0.5°C–1°C higher for 30 min in the hand bath group, compared with the no hand bath group. Therefore, hand baths appear to be effective not only for providing comfort and relaxation, but also for activating sympathetic nerve activity safely and positively.

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DISCLOSURE

The authors declare no conflict of interest.

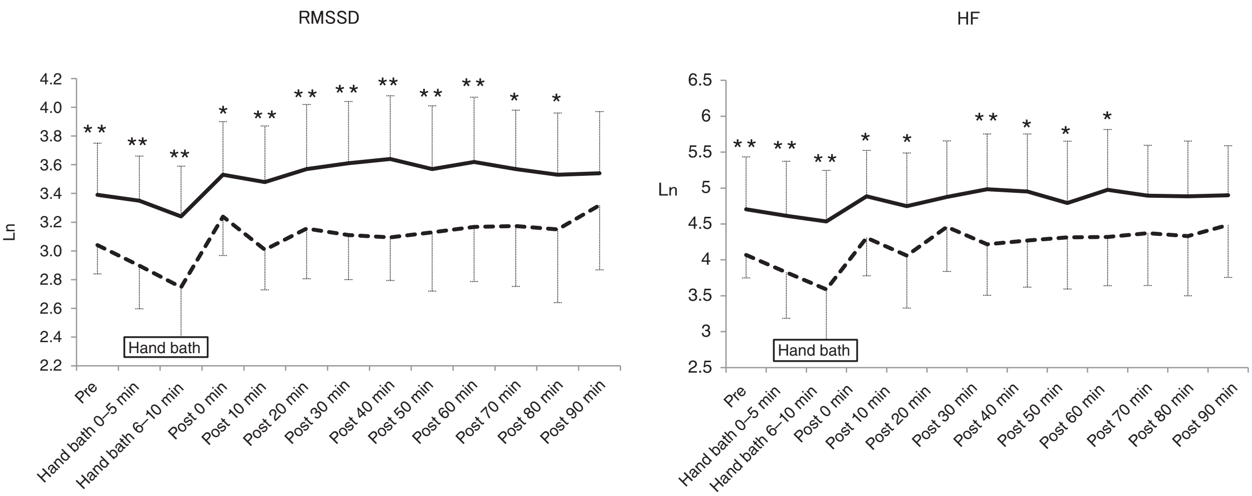

Figure 5 Comparison of the parasympathetic nervous activity between the constipation and no constipation groups. The root-mean-square of successive differences (RMSSD) of the normal-to-normal (NN) interval. *P < 0.05, **P < 0.01, and ***P < 0.001. —, no constipation group; ----, constipation group; HF, high frequency; Ln, converted to natural logarithms.

Table 6 Comparison of the visual analog scale scores between the hand bath and no hand bath groups

		Prehand bath			Posthand bath			Post30 min			Post60 min			Post90 min		
Variable	Group	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
VAS																
Feels good	H	41.1	20.8	NS	**73.7**	**13.1**	***	**66.4**	**13.4**	***	**62.0**	**12.1**	**	54.8	16.5	NS
	N	46.3	18.9		**47.2**	**20.0**		**47.0**	**20.2**		**50.4**	**21.4**		48.2	23.9	
Arm-to-shoulder comfort	H	38.9	19.5	NS	**66.9**	**17.8**	***	**61.5**	**16.5**	***	**55.7**	**16.2**	**	48.8	19.3	NS
	N	43.8	19.3		**44.8**	**21.2**		**45.1**	**20.8**		**44.7**	**21.5**		42.7	24.7	
Whole body comfort	H	41.1	19.8	NS	**66.5**	**17.2**	***	**62.1**	**14.8**	***	**55.8**	**14.8**	**	50.7	18.0	NS
	N	43.9	18.5		**45.0**	**20.5**		**44.7**	**20.8**		**44.2**	**20.0**		42.8	22.3	

**$P < 0.01$ and *** $P < 0.001$ according to hand bath group (H) *vs* no hand bath group (N). NS, non-significant; SD, standard deviation; VAS, visual analog scale. The bold values indicate those with significant differences.

AUTHOR CONTRIBUTIONS

Y. K. conducted the study; M. S., Y. K., R. S., M. H., and N. I. contributed research ideas and aspects of the study design, made suggestions regarding the content of the manuscript, and provided advice during the entire study process; including Y. K., they all contributed to the writing of the manuscript. All the authors approved the final version of the manuscript.

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