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Physiological and Psychological Effects of Different Foot Bath Water Depths on Female University Students

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Abstract

This study examined the physiological and psychological effects of different water depths during foot bathing in healthy female university students. Fifteen participants were randomly assigned to either a 5 cm or 15 cm water level groups. Baseline characteristics were recorded and changes in blood pressure, pulse rate, salivary amylase activity, and subjective assessments (fatigue, stress, relaxation, and sleep quality) were evaluated before and after the foot bath. Mood states were assessed using the Japanese version of the Profile of Mood States, Second Edition (POMS2). This study was approved by the ethics committees of the researchers' affiliated university. There were no significant changes in blood pressure, pulse rate, or salivary amylase activity in either group before and after foot bathing. However, in both groups, the VAS scores for physical fatigue and stress decreased significantly, whereas those for relaxation, refreshment, and warmth increased significantly. Additionally, the POMS2 scores for confusion-bewilderment, fatigue-inertia, and total mood disturbance decreased significantly. Comparisons between the two groups revealed no significant differences in any parameters. These findings suggest that foot baths at both the 5 cm and 15 cm water levels can promote relaxation and reduce fatigue and stress without imposing a physiological burden. Since a 5 cm water-level foot bath requires less water, it may serve as a practical and easily implementable intervention in home care, nursing, and caregiving settings.

Keywords

Foot Bath, Physiological and Psychological Effects, Female University Students

1. Background

Foot bathing is widely practiced in clinical settings to maintain body cleanliness, and its effects have been extensively studied. Previous research suggests that foot bathing may alleviate distress related to insomnia in individuals with difficulty falling asleep [1]-[5]. Additionally, it promotes emotional stability in postpartum women [6] and provides pain relief through thermal stimulation in patients who have undergone cardiac surgery [7].

Studies on the relaxation effects of foot bathing include research by Kito *et al.*, who conducted a 10-minute foot bath experiment on university students and found increased parasympathetic nervous activity and improved mood states, as assessed using a visual analog scale (VAS) [8]. Similarly, Oshima *et al.* reported that both aromatherapy and standard foot baths reduced confusion-bewilderment, depression-dejection, fatigue-inertia, and tension-anxiety scores on the Profile of Mood States (POMS), thereby enhancing relaxation [9].

However, the water levels in these studies varied, ranging from approximately 5 cm to 20 cm above the sole. Many standard nursing textbooks do not specify the optimal water level for foot bathing [10]-[12], and few provide concrete recommendations.

The triceps surae, often referred to as the "second heart," play a crucial role in promoting blood and lymphatic circulation in the lower body through muscle contraction [13]. Therefore, the water level and extent of lower limb immersion in warm water may influence physiological and psychological responses. Fujihira *et al.* compared the physiological effects of three water levels (42.0 cm, 21.0 cm, and 15.0 cm above the sole) and found that a 15 cm foot bath, which submerged the medial and lateral malleoli, was more effective in maintaining warmth than a full lower-leg bath [13]. However, their study did not examine the psychological effects.

Additionally, Shimizu *et al.* found no significant differences in physiological indicators, such as blood pressure, heart rate, autonomic nervous activity, or skin temperature, when comparing water levels of 8, 15, and 20 cm. However, they reported that the warming effect persisted for 30 minutes after a 15 cm foot bath [14]. Although there have been studies focusing on the water level of foot baths, the comparison of a normal water level of 15.0 cm with a shallow water level of 5 cm, which also requires less hot water, is quite novel. In addition, no randomized controlled trials (RCTs) focusing on water level have been conducted.

A higher water level requires more water, increasing the weight and making the preparations more cumbersome. Therefore, this study aimed to examine the physiological and psychological effects of foot baths at water levels of 15 cm and 5 cm. If a shallow 5 cm water bath provides comparable physiological and psychological benefits, it would reduce water consumption, making the setup and implementation more practical.

Therefore, this study aimed to determine the physiological and psychological effects of different foot bath water levels on healthy female university students. By

identifying variations in physiological and psychological responses, we aimed to establish the optimal water level that minimizes the physical burden of preparation and cleanup while maximizing the relaxation effects. These findings are expected to contribute to the development of safer and higher quality nursing care practices in clinical settings.

2. Operational Definition of Terms

In general nursing practice, foot bathing often involves washing the feet. However, for the purposes of this study, "foot bathing" is defined as the immersion of the feet in warm water.

3. Methods

3.1. Study Design

This was a RCT. Participants were randomly assigned (1:1) to the 5 cm or 15 cm water level groups using the envelope method. A third-party controller unrelated to the study randomly assigned participants, the controller randomly assigned participants to each group by sealing them in envelopes. The participants in each group were notified of the assignment results and the experiment was carried out.

3.2. Study Period

The study was conducted between September and October 2020.

3.3. Participants

The participants were 15 healthy female university students enrolled in a four-year university program. Owing to COVID-19-related constraints, the study period was limited, and participant recruitment was based on feasibility within the available timeframe.

3.4. Experimental Environment

The experiment was conducted at a comfortable location in each participant's home. The room temperature, humidity, seating, and foot bath placement were determined at the participants' discretion.

3.5. Experimental Procedure

Owing to the COVID-19 pandemic, foot bath equipment was shipped to the participants' homes, and the experiment was conducted independently. Instructions and written guidelines were provided via Zoom, with additional support available through email or LINE (LINE Corporation) as needed. A detailed instruction manual, including images of the equipment, was included with the shipment. All equipment were sanitized with disinfectant wipes before shipping to prevent infection.

To minimize the influence of the autonomic nervous system, participants were

instructed to sleep for at least 6 hours before the experiment and avoid alcohol, caffeine (e.g., coffee, tea, and energy drinks), and smoking on the day prior to the experiment.

The experimental procedure is illustrated in Figure 1. Baseline blood pressure, pulse rate, and salivary amylase activity were recorded before the foot bath. Mood states were assessed using the Japanese version of the POMS 2nd edition (POMS2), and subjective fatigue, stress, relaxation, and sleep quality were evaluated using a VAS.

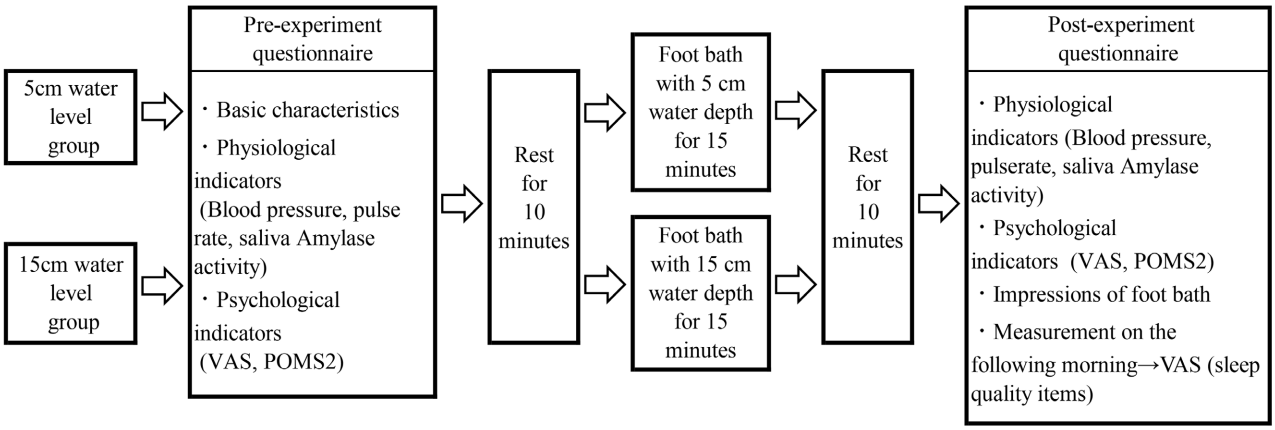

Figure 1. Experimental procedure.

After a 10-minute rest period, the participants prepared the foot bath using a foldable hot bubble foot bath device (SCS Corporation), filling it to their assigned water level. Once the water temperature reached 40˚C, they immersed both feet while seated and remained in the bath for 15 minutes. As an immersion exceeding 20 minutes has been reported to reduce comfort [15], the duration was set to 15 minutes to ensure sufficient warming and relaxation. The participants were instructed to discontinue the bath if the water felt excessively hot to avoid burns.

After the foot bath, excess water was wiped off with a towel, followed by a 10-minute rest period. Post-experimental measurements included blood pressure, pulse rate, and salivary amylase activity. Subsequently, POMS2 and VAS assessments were repeated, along with a survey of foot bath experience. Sleep quality was assessed using the VAS the following morning.

3.6. Survey Content

3.6.1. Experimental Environment and Basic Attributes of the Participants

The participants completed a questionnaire on room temperature, humidity, experimental location, age, usual sleep duration, sleep duration of the previous night, bathing habits, and foot bathing habits.

3.6.2. Physiological Indicators

Blood Pressure and Pulse Rate

Blood pressure and pulse rate were measured before and after the foot bath us-

ing an Omron HEM-7600T upper-arm blood pressure monitor, which allowed self-measurement.

Salivary Amylase Activity

Saliva samples were collected before and after the foot bath using a saliva collection strip placed under the tongue for 30 seconds. The salivary amylase activity was measured using a salivary amylase monitor (CM-2.1; Nipro Corporation). Salivary amylase activity is strongly correlated with plasma norepinephrine levels and is widely used as an objective indicator of sympathetic nervous system activation in stress evaluation with established reliability and validity [16].

Salivary amylase activity was categorized into four stress levels: 0 - 30 kIU/L: no stress, 30 - 45 kIU/L: slight stress, 46 - 60 kIU/L: moderate stress, and 61 - 200 kIU/L: high stress.

3.6.3. Psychological Indicators

VAS

The VAS was used to assess the following subjective states: physical fatigue, stress, drowsiness, relaxation, refreshment, warmth, tension, deep sleep, nightmares, ease of falling asleep, and wakefulness. Participants marked their state on a 10 cm horizontal line, with 0 mm indicating "not at all" and 100 mm indicating "extremely."

POMS2 (Japanese Short Version)

POMS2 is a 35-item questionnaire that assesses seven mood states using a five-point scale from "not at all" (0 points) to "extremely" (4 points). The original version was developed by McNair *et al.* in the U.S. and was later translated into Japanese. The measured mood states included anger-hostility (AH), confusion-bewilderment (CB), depression-dejection (DD), fatigue-inertia (FI), tension-anxiety (TA), vigor (VI), and friendliness (F).

The total mood disturbance (TMD) scores were calculated. The short version of the POMS2 was selected to reduce participant burden; its reliability and validity have been previously confirmed [17].

3.6.4. Foot Bath Experience

After the experiment, the participants evaluated the water volume, temperature, and overall impressions using multiple-choice and open-ended responses.

3.7. Data Analysis

Normality was assessed using the Shapiro-Wilk test. Group comparisons of experimental environmental factors were performed using the Mann-Whitney U test. Basic attributes were compared using Fisher's exact test and the Mann-Whitney U test. Within-group comparisons before and after foot bathing were analyzed using the Wilcoxon signed-rank test, whereas between-group comparisons of changes were analyzed using the Mann-Whitney U test. Statistical analyses were performed using IBM SPSS Statistics 25.0, with significance set at $p < 0.05$.

3.8. Ethical Considerations

Participants were informed that participation was voluntary and that withdrawal would not affect their academic performance. Non-faculty researchers recruited the participants to prevent coercion. Data were anonymized using research IDs and stored securely. Upon study completion, all data were disposed responsibly.

This study was approved by the Ethics Committee of the Graduate School of Health Sciences, Kobe University (Approval No. 942).

4. Results

4.1. Experimental Environment and Basic Attributes of the Participants

Of the 15 participants, seven and eight were assigned to the 5 cm and 15 cm water level groups, respectively. None of the participants dropped out of the study. The experimental conditions are listed in Table 1. There were no significant differences in room temperature or humidity between the two groups. Additionally, no significant differences were observed between the experimental locations used by the participants.

Table 2 presents the basic characteristics of the participants. The average age of the participants was 22.7 ± 0.8 years. All participants reported their daily bathing habits (including showering); however, none reported a habitual practice of foot bathing. No significant differences were found between the two groups for any of the basic attributes.

Table 1. Experimental environment.

	5 cm group (N = 7)	15 cm group (N = 8)	z/χ^2	P value
Room temperature[a)]	24.5 [20.0 - 26.0]	23.4 [22.6 - 26.7]	-0.174	0.862
Humidity[a)]	51.0 [48.0 - 67.0]	50.0 [43.0 - 57.8]	-0.581	0.561
Experiment location[b)]				
Living room	4 (57.1)	2 (25.0)	3.400	0.309
My Room	1 (14.3)	3 (37.5)		
Bathroom	1 (14.3)	3 (37.5)		
Others	1 (14.3)	0 (0.0)		

a) Mann-Whitney test, median [25 - 75 percentile]; b) χ^2 test.

Table 2. Basic characteristics among participants.

	Total (N = 15)	5 cm group (N = 7)	15 cm group (N = 8)	P value
Age (years)[a)]	22.7 ± 0.8	22.1 ± 1.0	22.0 ± 0.5	0.819
Usual sleep time (hours)[a)]	6.6 ± 1.0	6.7 ± 1.4	6.6 ± 1.4	0.951
Sleep time the previous day (hours)[a)]	6.7 ± 1.0	7.0 ± 1.0	6.5 ± 1.0	0.372
Bathing style[b)]				
Shower only	9 (60.0)	3 (42.9)	6 (75.0)	0.315
Soak in the bathtub	6 (40.0)	4 (57.1)	2 (25.0)	

Continued

Frequency of soaking in the bath[c)]				
Every day	4 (26.7)	4 (57.1)	0 (0.0)	0.106
4 - 5 times a week	2 (13.3)	0 (0.0)	2 (13.3)	
2 - 3 times a week	1 (6.7)	0 (0.0)	2 (13.3)	
Once a week	2 (13.3)	1 (14.3)	1 (6.7)	
0 times a week	6 (40.0)	2 (28.6)	2 (13.3)	
Regular foot bath habits				
Nothing	15 (100.0)	7 (100.0)	8 (100.0)	

a) Mann-Whitney test, median [25 - 75 percentile]; b) Fisher's exact test, N (%); c) χ^2 test.

4.2. Foot Bath Experience

Table 3 presents participants' evaluations of their foot bath experiences. Regarding water volume, six participants (75%) in the 15 cm group rated the volume as "appropriate," while one participant each found it "too little" or "too much." In contrast, all seven participants in the 5 cm group considered the water volume to be "too little" ($p = 0.003$).

Eight participants (four from each group) provided open-ended responses. Of these, seven participants (three and four from the 5 cm and 15 cm groups, respectively) described their experiences as "pleasant." Additionally, three participants (one and two from the 5 cm and 15 cm groups, respectively) reported feeling "relaxed," whereas one participant in the 5 cm group mentioned experiencing "lighter feet," and another described "a warming effect." However, some participants noted that "preparing for the experiment was bothersome" because of the self-administered nature of the study.

Table 3. Participants' impressions of the footbath.

		5 cm group (N = 7)	15 cm group(N = 8)	χ^2	P value
Amount of hot water	Too little	7 (100)	1 (12.5)	5.200	0.003**
	Optimal amount	0 (0)	6 (75.0)		
	Too much	0 (0)	1 (12.5)		
Temperature of hot water	Lukewarm	0 (0)	0 (0)	5.400	0.077
	Optimal	4 (57.1)	8 (100)		
	Too hot	3 (42.9)	0 (0)		

χ^2 test.

4.3. Changes in Physiological and Psychological Indicators in the 5 cm Group

Table 4 presents the pre- and post-foot bath comparisons of physiological and psychological indicators in the 5 cm group.

4.3.1. Physiological Indicators

No significant differences were observed in the systolic blood pressure, diastolic

blood pressure, pulse rate, or salivary amylase activity before and after the foot bath.

4.3.2. Psychological Indicators

In the VAS assessment, significant decreases were observed in physical fatigue ($z = -2.366$, $p = 0.018$) and stress ($z = -2.371$, $p = 0.018$), whereas significant increases were noted in relaxation ($z = -2.366$, $p = 0.018$), refreshment ($z = -2.375$, $p = 0.018$), warmth ($z = -2.371$, $p = 0.018$), and wakefulness ($z = -2.201$, $p = 0.028$).

In POMS2, significant decreases were observed in the following mood states: AH ($z = -2.060$, $p = 0.039$), CB ($z = -2.214$, $p = 0.027$), FI ($z = -2.214$, $p = 0.027$), and TA ($z = -2.207$, $p = 0.027$). Furthermore, the TMD score decreased significantly ($z = -2.375$, $p = 0.018$).

Table 4. Comparison of physiological and psychological indicators in the 5cm group before and after the experiment.

	Before the experiment		After the experiment		z	P value
Systolic blood pressure (mmHg)	108.0	[100.0 - 115.0]	110.0	[102.0 - 120.0]	0.000	0.203
Diastolic blood pressure (mmHg)	68.0	[64.0 - 73.0]	68.0	[64.0 - 71.0]	0.000	1.000
Pulse (Times/min)	69.0	[63.0 - 81.0]	63.0	[59.0 - 70.0]	−0.946	0.344
Salivary amylase (kIU/L)	43.0	[34.0 - 46.0]	41.0	[27.0 - 49.0]	−0.339	0.735
VAS (mm)						
Physical fatigue	60.0	[30.0 - 82.0]	19.0	[1.0 - 28.0]	−2.366	0.018*
Stress	42.0	[34.0 - 66.0]	14.0	[0.0 - 29.0]	−2.371	0.018*
Drowsiness	57.0	[18.0 - 83.0]	34.0	[21.0 - 72.0]	−0.676	0.499
Relaxed	50.0	[26.0 - 60.0]	88.0	[60.0 - 100.0]	−2.366	0.018*
Refreshing	34.0	[0.0 - 56.0]	80.0	[72.0 - 100.0]	−2.375	0.018*
Feel warm	30.0	[0.0 - 50.0]	92.0	[90.0 - 100.0]	−2.371	0.018*
Tensed	16.0	[0.0 - 35.0]	16.0	[1.00 - 10.0]	−0.210	0.833
Depth of sleep	72.0	[32.0 - 78.0]	72.0	[68.0 - 74.0]	−1.014	0.310
Having nightmares	18.0	[13.0 - 45.0]	13.0	[1.0 - 23.0]	−1.153	0.249
Falling asleep easily	60.0	[18.0 - 85.0]	70.0	[64.0 - 100.0]	−1.782	0.075
Quality of awakening	54.0	[27.0 - 67.0]	82.0	[67.0 - 100.0]	−2.201	0.028*
POMS (Score)						
Anger-Hostility (AH)	2.0	[1.0 - 3.0]	0.0	[0.0 - 1.0]	−2.060	0.039*
Confusion-Bewilderment (CB)	2.0	[2.0 - 3.0]	0.0	[0.0 - 2.0]	−2.214	0.027*
Depression-Dejection (DD)	1.0	[1.0 - 2.0]	0.0	[0.0 - 2.0]	−1.725	0.084
Fatigue-Inertia (FI)	5.0	[3.0 - 8.0]	2.0	[0.0 - 3.0]	−2.214	0.027*
Tension-Anxiety (TA)	5.0	[2.0 - 9.0]	1.0	[0.0 - 5.0]	−2.207	0.027*
Vigor-Activity (VA)	10.0	[4.0 - 15.0]	13.0	[9.0 - 15.0]	−1.367	0.172
Friendliness (F)	14.0	[9.0 - 17.0]	13.0	[8.0 - 17.0]	−0.412	0.680
Total Mood Disturbance (TMD)	5.0	[2.0 - 9.0]	−9.0	[−12.0 - −2.0]	−2.375	0.018*

Wilcoxon signed-rank test, median [25 - 75 percentile]; VAS; visual analog scale; POMS; profile of mood states; *$p < 0.05$.

4.4. Changes in Physiological and Psychological Indicators in the 15 cm Group

Table 5 presents the pre- and post-foot bath comparisons of the physiological and psychological indicators in the 15 cm group.

Table 5. Comparison of physiological and psychological indicators in the 15cm group before and after the experiment.

	Before the experiment		After the experiment		z	P value
Systolic blood pressure (mmHg)	105.5	[101.3 - 110.0]	101.0	[95.8 - 109.3]	−0.632	0.528
Diastolic blood pressure (mmHg)	61.5	[54.0 - 65.3]	60.5	[52.3 - 69.0]	−0.350	0.726
Pulse (Times/min)	66.6	[61.5 - 76.3]	69.0	[63.0 - 82.5]	−1.183	0.237
Salivary amylase (kIU/L)	32.0	[16.8 - 74.3]	36.0	[19.5 - 111.0]	−0.421	0.674
VAS (mm)						
Physical fatigue	59.0	[26.5 - 67.0]	26.5	[16.8 - 50.0]	−2.197	0.028*
Stress	56.5	[52.5 - 58.0]	22.0	[16.5 - 54.0]	−2.100	0.036*
Drowsiness	64.0	[29.3 - 76.3]	66.0	[32.5 - 77.8]	−0.280	0.779
Relaxed	37.0	[27.5 - 66.3]	74.5	[62.0 - 83.8]	−2.371	0.018*
Refreshing	24.5	[20.0 - 38.0]	66.5	[59.5 - 71.5]	−2.527	0.012*
Feel warm	29.5	[8.5 - 51.0]	78.0	[73.0 - 82.3]	−2.521	0.012*
Tensed	22.5	[9.0 - 37.3]	11.5	[1.5 - 22.0]	−1.260	0.208
Depth of sleep	62.0	[29.3 - 73.0]	70.0	[59.8 - 81.5]	−1.820	0.069
Having nightmares	7.0	[3.5 - 35.0]	4.5	[0.3 - 21.3]	−0.734	0.463
Falling asleep easily	34.0	[27.3 - 62.5]	57.5	[36.8 - 81.5]	−2.254	0.024*
Quality of awakening	31.0	[25.0 - 68.8]	59.5	[45.8 - 69.8]	−0.183	0.183
POMS (Score)						
Anger-Hostility (AH)	1.5	[0.0 - 3.8]	0.0	[0.0 - 3.0]	−1.289	0.197
Confusion-Bewilderment (CB)	5.0	[4.3 - 5.8]	3.0	[1.3 - 3.8]	−2.388	0.017*
Depression-Dejection (DD)	2.0	[0.3 - 7.3]	1.5	[0.0 - 4.0]	−1.633	0.102
Fatigue-Inertia (FI)	5.5	[3.3 - 7.8]	3.5	[0.8 - 4,8]	−2.207	0.027*
Tension-Anxiety (TA)	4.0	[2.3 - 6.5]	2.5	[0.3 - 4.8]	−1.527	0.127
Vigor-Activity (VA)	6.5	[2.0 - 6.8]	4.5	[2.3 - 1.0]	−0.281	0.778
Friendliness (F)	9.0	[7.3 - 13.5]	9.0	[6.5 - 12.5]	−0.520	0.603
Total Mood Disturbance (TMD)	17.0	[8.5 - 18.8]	5.5	[−1.8 - 15.0]	−2.524	0.012*

Wilcoxon signed-rank test, median [25 - 75 percentile]; VAS; visual analog scale; POMS; profile of mood states; *$p < 0.05$.

4.4.1. Physiological Indicators

Similar to the 5 cm group, no significant differences were observed in the systolic blood pressure, diastolic blood pressure, pulse rate, or salivary amylase activity before and after the foot bath.

4.4.2. Psychological Indicators

In the VAS assessment, significant decreases in physical fatigue ($z = −2.197$, $p = 0.028$) and stress ($z = −2.100$, $p = 0.036$) were observed. In contrast, significant

increases were noted in relaxation (z = −2.371, p = 0.018), refreshment (z = −2.527, p = 0.012), warmth (z = −2.521, p = 0.012), and ease of falling asleep (z = −2.254, p = 0.024).

In the POMS2, significant decreases were observed in CB (z = −2.388, p = 0.017), FI (z = −2.207, p = 0.027), and TMD (z = −2.524, p = 0.012).

4.5. Comparison of Changes between the Two Groups

Table 6 presents a comparison of physiological and psychological changes between the two groups. No significant differences were observed in any of the measured parameters.

Table 6. Comparison of the changes in physiological and psychological indicators between the two groups before and after the experiment (change = post-experiment value − pre-experiment value).

	5 cm group (N = 7)		15 cm group (N = 8)		z	P value
Systolic blood pressure (mmHg)	2.0	[−2.0 - 8.0]	−1.5	[−15.8 - 7.0]	−0.873	0.383
Diastolic blood pressure (mmHg)	1.0	[−4.0 - 4.0]	−2.0	[−10.5 - 16.3]	0.174	0.862
Pulse (Times/min)	0.0	[−16.0 - 1.0]	2.5	[−1.5 - 12.5]	−1.513	0.130
Salivary amylase (kIU/L)	6.0	[−14.0 - 7.0]	0.0	[−9.0 - 58.0]	−0.406	0.685
VAS (mm)						
Physical fatigue	−32.0	[−45.0 - −14.0]	−13.0	[−36.5 - −2.0]	−1.448	0.148
Stress	−28.0	[−66.0 - −10.0]	−28.0	[−37.3 - −2.5]	−0.290	0.772
Drowsiness	−2.0	[−24.0 - −13.0]	1.0	[−32.0 - 36.3]	−0.348	0.728
Relaxed	34.0	[23.0 - 74.0]	19.5	[5.8 - 47.0]	−1.158	0.247
Refreshing	38.0	[24.0 - 100.0]	40.0	[31.5 - 47.3]	−0.348	0.728
Feel warm	61.0	[42.0 - 90.0]	50.5	[36.0 - 66.8]	−1.276	0.202
Tensed	0.0	[−8.0 - 3.0]	−7.5	[−27.0 - 7.0]	−0.637	0.524
Depth of sleep	12.0	[−5.0 - 30.0]	17.5	[−8.3 - 41.0]	−0.463	0.643
Having nightmares	−16.0	[−22.0 - 0.0]	−2.0	[−9.3 - 1.5]	−1.045	0.296
Falling asleep easily	26.0	[0.0 - 47.0]	12.0	[3.0 - 31.8]	−0.348	0.728
Quality of awakening	28.0	[2.0 - 64.0]	24.5	[−14.8 - 38.3]	−0.521	0.602
POMS (Score)						
Anger-Hostility (AH)	−2.0	[−2.0 - 0.0]	0.0	[−1.8 - 0.0]	−1.329	0.184
Confusion-Bewilderment (CB)	−2.0	[−3.0 - −1.0]	−2.0	[−2.8 - −1.0]	−0.119	0.905
Depression-Dejection (DD)	−1.0	[−2.0 - 0.0]	−0.5	[−3.0 - 0.0]	−0.177	0.859
Fatigue-Inertia (FI)	−3.0	[−4.0 - −2.0]	−1.5	[−5.3 - −0.3]	0.877	0.381
Tension-Anxiety (TA)	−2.0	[−5.0 - −1.0]	−1.5	[−3.8 - 0.8]	−1.049	0.294
Vigor-Activity (VA)	2.0	[−1.0 - 5.0]	0.0	[−2.5 - 1.0]	−0.815	0.415
Friendliness (F)	0.0	[−2.0 - 2.0]	−0.5	[−2.5 - 1.0]	0.000	1.000
Total Mood Disturbance (TMD)	−14.0	[−17.0 - −12.0]	−4.5	[−17.5 - −2.3]	−1.395	0.163

Wilcoxon signed-rank test, median [25 - 75 percentile]; VAS; visual analog scale; POMS; profile of mood states.

5. Discussion

We conducted a RCT to investigate the physiological and psychological effects of different foot bath water levels (5 cm and 15 cm) on female university students.

5.1. Comparison of Physiological and Psychological Effects between the 5 cm and 15 cm Groups

No significant differences were observed in systolic blood pressure, diastolic blood pressure, pulse rate, or salivary amylase activity before and after foot bathing between the 5 cm or 15 cm groups. These findings are consistent with those of Shimizu *et al.*, who reported no significant differences in blood pressure or pulse rate based on water levels [14].

In contrast, Nagaie *et al.* examined the effects of 41˚C bathing on the circulatory system in healthy individuals. They found that when participants were immersed up to the chest level in 41˚C water for 10 minutes, both systolic blood pressure and pulse rate significantly increased, resulting in a cardiovascular load [18]. In the present study, even though foot bathing was conducted for a relatively long duration of 15 minutes at 40˚C, minimal effects on the circulatory system were observed. This aligns with previous studies on foot bathing, which also found that partial immersion affects the circulatory system less than full-body immersion.

Foot bathing, which is a partial immersion method, imposes less strain on the body than full-body bathing. This suggests that it may be a viable low-cardiovascular-load hygiene care option for older adults. Future studies should broaden the participant pool to include individuals with cardiovascular diseases and older individuals to further validate these findings.

A decrease in salivary amylase activity was expected owing to the stress reduction associated with foot bathing. However, while the values decreased in the 5 cm group without reaching statistical significance, an increase was observed in the 15 cm group after foot bathing. Salivary amylase activity levels between 30 and 45 kIU/L were classified as mild stress. In both the groups, the median value exceeded 30 kIU/L before and after foot bathing. Because the participants measured their own salivary amylase activity in this study, the procedure may have been inconvenient or burdensome, potentially causing stress and influencing the results. Furthermore, the requirement for participants to prepare for and conduct the experiment themselves may have imposed both physical and psychological stress.

To facilitate this procedure, a visually intuitive paper-based instruction manual was provided as reference during the experiment. In future studies, incorporating real-time online guidance along with written instructions during data collection may help reduce participant burden and improve measurement accuracy.

In both the 5 cm and 15 cm groups, significant decreases were observed in the VAS scores for physical fatigue and stress, as well as in the POMS2 scores for CB and FI. These results suggest that foot bathing effectively reduces fatigue and stress. Additionally, both groups showed significant increases in VAS scores for relaxation, refreshment, and warmth, indicating the potential relaxation effects of

foot bathing under both conditions.

In this study, the 15 cm group was expected to experience a greater warming effect owing to the larger surface area of the lower limbs being submerged in water. However, the VAS score for the sensation of warmth was higher in the 5 cm group.

Regarding the effects of foot bathing on body temperature, Fujihira *et al.* found that in a group immersed up to the middle of the lower leg, the surface temperature decreased, whereas in a group immersed up to the medial and lateral malleoli, little change in surface temperature was observed [13]. They suggested that when the immersion reaches the middle of the lower leg, evaporative heat loss from the wet skin surface after foot bathing may contribute to a decrease in surface temperature.

Similar to previous findings, the 15 cm group in this study was immersed up to the middle of the lower leg, which could explain the occurrence of evaporative heat loss. In nursing practice for foot bathing, drying the lower limbs immediately and providing insulation with a towel after foot bathing is recommended to prevent heat loss through evaporation.

The instruction manual for this experiment included a note instructing participants to "ensure that the skin is dried immediately after foot bathing, preparing a towel in advance before the experiment." However, whether the participants were able to prepare the towels themselves or whether they effectively dried their skin post-foot bath could not be verified. Future studies may benefit from closer monitoring of this aspect to ensure accurate implementation of post-bath drying instructions.

In the future, providing more detailed explanations of the key points and considering methods, such as conducting an experiment with ongoing online communication, will be necessary to ensure better support and guidance for participants.

Furthermore, in this study, warmth perception was measured using only subjective VAS scores. Future research should incorporate objective physiological measures such as core body temperature and skin surface temperature to offer a more comprehensive assessment of the warming effects of foot bathing.

Apart from the "warm" item on the VAS, significant decreases were observed in the physical fatigue and stress items, whereas significant increases were observed in the "relaxed" and "refreshed" items. Oshima *et al.* demonstrated that foot bathing had a relaxation effect, as indicated by the VAS [9]. Similar results were obtained in the present study, suggesting that foot bathing may contribute to fatigue recovery and stress reduction, and potentially offer relaxation benefits.

In addition, the POMS2 scores for CB and FI significantly decreased in both the 5 cm and 15 cm groups. Fuse *et al.* reported that foot bathing positively reduced negative moods such as CB, depression-despair, FI, and TA [19]. The results of the present study are consistent with those of previous studies.

Notably, when comparing the changes in each indicator before and after the

experiment between the two groups, no significant differences were observed. However, the fact that both groups showed relaxation effects in this study suggests that foot bathing has relaxation benefits, regardless of the water level. Normally, it is thought that a larger amount of water at a water depth of 15 cm would make one feel warmer. The results of this study show that the VAS score for warmth was high in the 5 cm group, suggesting that it is possible that a smaller amount of water can make one feel warm. In the future, we will increase the number of subjects and conduct further surveys to examine the warmth, psychological effects, and physiological effects of water at a lower depth.

On the other hand, Regarding the results in which no physiological changes were observed and only significant psychological effects were observed, it is possible that the psychological effects are mediated by mechanisms other than autonomic nervous activity, such as the placebo effect or increased participants' comfort. Therefore, it is necessary to plan and conduct future studies that also include the effects of other factors.

5.2. Application to Nursing

This study confirmed that a 5 cm water level during foot bathing can provide the same relaxation effects as a 15 cm water level. A foot bath with a water level of 5 cm requires a small amount of water, which shortens the preparation time and improves time efficiency. However, if the amount of water is small, the water temperature will quickly cool down if the foot bath container does not have a temperature maintenance device, so it is recommended to use a foot bath container that can maintain the temperature. A foot bath with a water level of 5 cm can reduce the burden of preparation and cleanup for nurses in busy clinical settings. This makes the incorporation of foot bathing into daily living assistance feasible.

Furthermore, in clinical settings, where care is often provided to patients with cardiovascular diseases or older individuals, foot bathing can be implemented as a hygienic care method that exerts minimal cardiovascular strain on such individuals.

Additionally, in this study, the participants were asked to perform foot bathing at home. As foot bathing can be performed with a small amount of water in the home environment, this practice could easily be introduced into home care settings and integrated into daily life.

5.3. Limitations

The participants in this study were healthy female students in a university, with a small sample size of 15 individuals. This may have affected statistical power and the possibility of type II error, especially in physiological indicators, which were not significant. Future research should involve a broader range of participants with varying conditions to determine the generalizability of the findings.

Additionally, owing to the impact of COVID-19, the participants were asked to take a foot bath in their own way during their daily lives. The method of wiping the feet after the foot bath was done in the way that they usually did, and the re-

searchers did not specify anything. Therefore, the way of drying the feet, such as wiping after a foot bath, may have affected the results.

To ensure that the experimental procedures are strictly followed, standardizing the conditions by monitoring the participants through remote cameras, such as Zoom, is necessary to verify adherence to the methodology.

On the other hand, the unexpected increase in salivary amylase in the 15 cm group is in contrast to the stress reduction stated in the original hypothesis and requires more detailed investigation. Future studies may benefit from including a control group, such as a non-heated foot bath, to account for potential confounding factors such as self-measured procedural stress and to more clearly isolate the effects of heat.

6. Conclusions

In this study, 15 healthy female university students were assigned to either the 5 cm or 15 cm water level groups to examine the physiological and psychological effects of different water levels during foot bathing.

In terms of physiological indicators, the results were largely consistent between the two groups. Regarding psychological indicators, both groups showed significant reductions in physical fatigue and stress on the VAS and in CB and FI on the POMS2. These findings suggest that foot bathing effectively reduces fatigue and stress. Furthermore, both the 5 cm and 15 cm groups demonstrated significant increases in VAS scores for feeling refreshed and warm, indicating that relaxation effects were achieved regardless of the water level.

The fact that the same level of relaxation can be achieved with a smaller amount of water suggests that foot bathing could reduce the burden of preparation and clean-up in nursing settings as well as in home care, making it easier to implement and incorporate into daily routines.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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