

Effect of a steam foot spa on geriatric inpatients with cognitive impairment: a pilot study

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Purpose: To investigate whether a steam foot spa improves cognitive impairment in geriatric inpatients.

Methods: Geriatric inpatients with cognitive impairment were given a steam foot spa treatment at 42°C for 20 minutes for 2 weeks (5 days/week). Physiological indicators such as blood pressure, percutaneous oxygen saturation, pulse, tympanic temperature, and sleep time and efficiency were assessed. Cognitive function and behavioral and psychological symptoms of dementia were assessed using the Mini-Mental State Examination, Dementia Mood Assessment Scale, and Dementia Behavior Disturbance scale.

Results: Significant decreases in systolic ($P < 0.01$) and diastolic blood pressure ($P < 0.05$) along with a significant increase in tympanic temperature ($P < 0.01$) were observed after the steam foot spas. A significant improvement was seen in the Mini-Mental State Examination score ($P < 0.01$) and the overall dementia severity items in Dementia Mood Assessment Scale ($P < 0.05$).

Limitations: Japanese people are very fond of foot baths. However, it is difficult to understand why inpatients cannot receive steam foot baths. In this study, a control group was not used. Raters and enforcers were not blinded.

Conclusion: The results of this pilot study suggest that steam foot spas mitigate cognitive impairment in geriatric inpatients.

Keywords: steam foot spa, geriatric inpatients, cognitive impairment, tympanic temperature

Introduction

The geriatric inpatient occupancy rate is more pronounced in the elderly because of dementia regardless of the acute or chronic stage. In addition, the mortality rate is higher in patients with dementia than in those without.^{1–3} Moreover, acute hospital mortality from dementia tends to increase in proportion to dementia severity.⁴ Furthermore, hospitalized patients with dementia show further increased mortality and prolonged hospitalization.⁵ Thus, mitigating such cognitive impairment in geriatric inpatients is an urgent task.

A recent study reported that cholinergic neurons are involved in improving cognitive function because these neurons are involved in memory and attention.⁶ In addition, these neurons activate vasodilators.^{7,8} Vascular endothelial cells are located on the inner wall of the components of the cardiovascular system. Nitric oxide is produced by vascular endothelial cells and induces relaxation of vascular smooth muscle cells.⁹ Furthermore, it increases cerebral blood flow, which in turn is induced by cerebral microvascular extensions. Cholinergic neurons are activated by

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somatosensory stimuli.¹⁰ These observations suggest that cholinergic neurons are activated by somatosensory stimulation, improving attention and memory; both blood pressure and cerebral blood flow temperature are physiological indicators that confirm this effect.

Kihara et al treated 30 patients with chronic heart failure with a system of dry sauna baths for 10 days using far infrared light at 60°C for 15 minutes with the patient in a supine position in bed, followed by rest and heat retention by wrapping the entire body for 30 minutes with the room temperature set at 24°C. This treatment improved ventricular arrhythmia in these patients.¹¹ Higashi et al provided 15-minute steam foot baths at 42°C for 2 weeks to a 21-year-old male with severe chronic heart failure who required a left ventricular assist device, followed by a 30-minute rest and heat retention in bed. They reported improved cardiac function. Taken together, a steam foot spa is expected to be useful for treating heart failure as a substitute for dry sauna or steam stimulation at 42°C for 15 minutes for 2 weeks (5 days/week).¹² In summary, steam stimulation acts as a somatosensory stimulus to activate cholinergic neurons, and memory and attention are expected to improve by implementing this therapy.

This study aimed to investigate the effects of steam foot spas on mitigating cognitive impairment in geriatric inpatients.

Material and methods

Subjects

The geriatric hospital in this study was located on the outskirts of Okayama City, which is the capital of Okayama Prefecture and has a population of approximately 750,000. The subjects were 200 medical and psychiatric inpatients with mild-to-moderate cognitive impairment. The reason for choosing the subjects was that the damage of the cholinergic neurons is proportional to the severity of cognitive impairment.¹³

The ethics committee of Yoshiigawa Hospital approved this study. A full explanation was given to all patients who were interested in the study, and written informed consent was obtained from the 13 inpatients (or a family member on their behalf) who agreed to participate (Table 1).

Stimuli

There are approximately 2600 hot spring facilities in Japan because many Japanese prefer a full bath; many of these facilities include foot baths. In this study, a bathtub with 28 cm deep hot water set at 43.6°C ± 0.2°C and an outdoor temperature of 20°C was used and the effects of a footbath

Table 1 Characteristics of study participants (n = 13)

Characteristic	Subjects
Age, years (mean ± SD)	82.69 ± 6.53
Sex	
Male	2
Female	11
Physical and mental condition	
Cognitive impairment (MMSE score 12–24)	13
Depression	5
Depressive neurosis	1
Hypertension	10
Hypotension	1
Cardiac insufficiency	2

Abbreviations: MMSE, Mini-Mental State Examination; SD, standard deviation.

on tympanic temperature, pulse, and blood pressure in nine healthy males (average age 73.5 ± 2.6 years) were studied. As a result, diastolic and systolic blood pressure decreased significantly after 15 and 20 minutes, respectively. Higashi et al provided 15-minute steam foot baths at 42°C for 2 weeks and Kihara et al provided 15 minutes of far infrared light at 60°C for 10 days.^{11,12} In reference to their studies, a steam foot spa at a temperature of 42°C was provided for 20 minutes a day for 10 days.

Steam foot spas were given for 20 minutes in a physical therapy room with the temperature maintained at 24°C from 10:00 to 12:00 for 2 weeks excluding weekends (ten times in total). The steam foot spa was EH2862P-W (Panasonic Corporation, Osaka, Japan), which could be used in two ways: combined intermittent jet-style steam and far infrared light or steam alone. Temperature could be set at six levels from 42°C–46°C. Steam only was used with a temperature of 42°C for 20 minutes.

Outcome measures

Rating scales

The rating scale used to evaluate cognitive impairment was the Mini-Mental State Examination (MMSE). Behavioral disturbances were assessed using the Dementia Behavior Disturbance (DBD) scale. Depression was assessed using the Dementia Mood Assessment Scale (DMAS). For each patient, DMAS, MMSE, and DBD scores were recorded at the same time before the steam foot spas and after 2 weeks of treatment.

Examination of sadness and depression

Sadness and depression were assessed using DMAS, which is a 24-item (score 0–144) observational scale used to objectively rate mood and functional abilities.¹⁵ The first 17 items are designed to measure mood in cognitively impaired

subjects and the last seven items are designed to measure cognitive and functional impairment. The mood subscale has a maximum score of 102, with a higher score representing greater dysphoria. Sunderland et al reported that scores are significantly correlated with global measures of depression ($r = 0.73$) and sadness ($r = 0.65$). Inter-rater reliability was highly satisfactory.¹⁶ In this study, sadness and depression were evaluated in subjects using a subtotal (score 0–102) from items one to 17 of DMAS.

Examination of cognitive performance

MMSE (score 0–30), which has been used worldwide, was utilized to examine the severity of cognitive performance.¹⁷

In addition, a subtotal (score 0–42) score from items 18–24 of DMAS was used to evaluate overall cognitive performance.

Behavioral disturbance

Behavioral disturbance was assessed using the DBD scale (score 0–168), which is a 28-item scale developed to avoid some of the problems encountered with older instruments.¹⁸ Each of the 28 items was designed to be used in an interview format, with the patient's primary caregiver as the respondent. Each behavior was rated on a Likert-type scale with five possible responses corresponding to the frequency of the behavior in the preceding week (zero = never, four = all the time). Thus, higher scores indicate greater behavioral disturbance. The reliability and validity of the Japanese version of the DBD scale have been established previously.¹⁹

Examination of physiological responses

Physiological response measurements were performed after the 15-minute rest and immediately after the steam foot spa treatment.

Tympanic temperature

Tympanic temperature was measured using a Terumo ear type thermometer (EM-30 CPL; Terumo Corporation, Tokyo, Japan). This equipment complies with the standards of the American Society for Testing and Materials. Saito et al reported that a maximum of three measurements by nonexperts and experts are highly positively correlated ($r = 0.77$, $n = 60$) for axillary temperature.²⁰ The maximum range in the values of three measurements was $0.09^{\circ}\text{C} \pm 0.09^{\circ}\text{C}$. Tympanic temperature was measured three times before and after each steam foot spa treatment, and the highest value was used for analysis.

Percutaneous oxygen saturation (SpO_2)

SpO_2 levels were measured with a finger pulse oximeter (EPOCH 30; Ubix Corporation, Tokyo, Japan).

Blood pressure and pulse

Blood pressure and pulse were measured using an Omron digital wrist-type automatic sphygmomanometer (HEM-632; Omron Corporation, Kyoto, Japan).

Sleeping hours and sleep efficiency

Sleeping hours and efficiency were measured using a wrist-watch-type actigraph (MicroMini RC; Ambulatory Monitoring Inc, Ardsley, NY, USA).²¹ The findings of this actigraph are reported to show 90% or more agreement with those of sleep polygraphy. It uses a sleep–wake distinction software approved by the American Academy of Sleep Medicine.²² Measurements were conducted for 16 days, except during bathing, from the day before the steam foot spa treatment until a day after the steam foot spa treatment, thus enabling each patient's circaseptan rhythm (a 7-day cycle in which biological processes such as blood pressure and heart rate show improvement) to be determined.^{23–25}

Intervention

Scores on MMSE, DMAS, and DBD were evaluated by ward nurses. A full-time registered physical therapist conducted the steam foot spas; blood pressure, SpO_2 , pulse, and tympanic temperature were measured by a full-time assistant physical therapist. These data (including the actigraph data) were statistically analyzed.

Data analysis

Data were analyzed using SPSS software version 16.0 (SPSS Inc, Chicago, IL, USA). The Wilcoxon signed-rank test was used to detect differences in the results with a significance level of 0.05.

Results

The 13 geriatric inpatients showed a significant increase in total MMSE scores ($P < 0.01$) after 10 days of steam foot spa treatment. In addition, a significant improvement was seen in the overall dementia severity items on DMAS ($P < 0.05$) (Table 2).

No significant differences were observed for the sadness and depression (first 17 items) items on DMAS. Furthermore, no significant improvements were seen in total sleep time, night-time sleep, or night-time sleep efficiency measured by actigraphy, which can also be used to assess depression.²⁵

Table 2 Effect of steam foot spa treatments on cognitive function, behavioral symptoms, and psychological symptoms

Assessment tool	Before (mean $\pm$ SD)	After (mean $\pm$ SD)
DBD	16.31 $\pm$ 7.28	17.31 $\pm$ 8.17
DMAS (total 24 items)	40.00 $\pm$ 13.57	34.77 $\pm$ 16.20
Depression and sadness (items 1–17)	31.46 $\pm$ 11.37	27.84 $\pm$ 14.07
Overall dementia severity (items 18–24)	8.54 $\pm$ 4.55	6.92 $\pm$ 3.87*
MMSE	18.38 $\pm$ 3.69	22.92 $\pm$ 3.97**

Notes: n = 13; *P < 0.05; **P < 0.01.

Abbreviations: MMSE, Mini-Mental State Examination; DBD, Dementia Behavior Disturbance scale; DMAS, Dementia Mood Assessment Scale; SD, standard deviation.

Moreover, no significant differences in DBD, a problem behavior assessment scale, were observed (Table 2).

These results suggest that a steam foot spa did not affect the behavioral and psychological symptoms of dementia, such as depression and problem behavior. However, it seems to affect cognitive impairment.

Both systolic ($P < 0.01$) and diastolic blood pressure ($P < 0.05$) decreased significantly after 10 days of foot spa treatment. Fluctuations in systolic blood pressure were seen in all patients. However, both mean systolic and diastolic blood pressure values in one patient with low blood pressure increased before and after the steam foot spa treatment (thereby decreasing the significant difference) (Table 3). In addition, tympanic temperature, which reflects internal carotid artery temperature, increased significantly immediately after the steam foot spa treatment ($P < 0.01$). However, the average tympanic temperature 10 days prior to treatment

was low, which was considered to be a result of high blood pressure (Table 4).

No significant change was seen in SpO₂ level or pulse. These results suggest that systemic vasodilatation was affected by the steam foot spa.

Discussion

The cholinergic nervous system, which projects from the nucleus basalis of Meynert in the basal forebrain to the cerebral cortex and from the septal region to the hippocampus, dilates the blood vessels in the cerebral cortex and hippocampus.^{6,7} Hotta et al reported that intermittent occlusion of a unilateral common carotid artery in rats decreased blood flow by 13%–32%, but that the decrease in blood pressure was almost completely blocked by activating vasodilator nerves originating in the nucleus basalis of Meynert.⁸ Piche et al increased nucleus basalis of Meynert nerve activity with somatosensory stimulation and found that acetylcholine was released and blood flow increased in the cerebral cortex.¹⁰ Activation of the nicotinic acetylcholine nervous system enhances the neuroprotective effect to promote increased secretion of nerve growth factor.²⁶

In this study, cerebral blood flow increased with the increase in tympanic temperature caused by the steam foot spa treatments for geriatric inpatients. This effect was considered to activate the brain and consequently raise the temperature of the internal carotid artery.^{27,28} Another possibility is that the patient's tympanic temperature tended to be low because of hypertension. However, hypertension decreased

Table 3 Fluctuations in blood pressure with steam foot spa

	Systolic blood pressure (mmHg)			Diastolic blood pressure (mmHg)		
	Before (mean)	After (mean)	Variance	Before (mean)	After (mean)	Variance
1	147.7	142.5	−5.2	93.7	89.1	−4.6
2	160.5	139.5	−21.0	83.1	68.7	−14.4
3	138.3	130.3	−8.0	76.2	70.8	−5.4
4	124.5	116.9	−7.6	83.3	77.4	−5.9
5	87.6	94.1	+6.5	47.7	61.2	+13.5
6	147.3	140.8	−6.5	78.7	75.3	−3.4
7	152.8	132.4	−20.4	95.0	82.8	−12.2
8	154.3	140.0	−14.3	77.8	73.9	−3.9
9	151.6	115.1	−36.5	79.6	64.5	−15.1
10	133.5	129.5	−4.0	81	72.9	−8.1
11	162.8	160.5	−2.3	90.3	94.3	+4.0
12	154.7	136.7	−18.0	78.5	68.5	−10.0
13	158.0	120.5	−37.5	80.7	69.3	−11.4
Mean $\pm$ SD	144.12 $\pm$ 5.6	130.68 $\pm$ 4.53	14.45 $\pm$ 11.32	80.43 $\pm$ 3.21	74.512 $\pm$ 2.62	8.83 $\pm$ 4.27

Note: Each value is the average of the values of blood pressure for 10 days.

Abbreviation: SD, standard deviation.

Table 4 Effect of steam foot spa treatments on physiological responses and on sleep–wake rhythm

Physiological responses	Before (mean $\pm$ SD)	After (mean $\pm$ SD)
Tympanic temperature ($^{\circ}$ C)	35.87 $\pm$ 0.37	36.14 $\pm$ 0.36**
SpO ₂ (%)	96.56 $\pm$ 1.22	96.43 $\pm$ 1.28
Pulse (beats/minute)	69.23 $\pm$ 8.61	69.05 $\pm$ 8.63
Systolic blood pressure (mmHg)	144.12 $\pm$ 19.42	130.68 $\pm$ 15.72**
Diastolic blood pressure (mmHg)	80.43 $\pm$ 11.11	74.51 $\pm$ 9.09*
Sleep–wake rhythm	First week (mean $\pm$ SD)	Second week (mean $\pm$ SD)
Total sleep time (minutes)	531.37 $\pm$ 134.77	555.95 $\pm$ 139.05
Night-time sleep (minutes)	383.18 $\pm$ 133.94	367.18 $\pm$ 122.96
Night-time sleep efficiency (%)	85.21 $\pm$ 7.36	85.72 $\pm$ 8.69

Notes: n = 13; *P < 0.05; **P < 0.01.

Abbreviations: SD, standard deviation; SpO₂, percutaneous oxygen saturation.

because of the steam foot spa treatment, thus secondarily increasing the tympanic temperature.

A significant antihypertensive effect was observed in this pilot study. However, although blood pressure decreased significantly after 20 minutes of treatment, heart rate did not change. Cholinergic nerves cause vasodilatation; however, no sustained excitability of these nerves occurred. Thus, no change in heart rate variability was observed. The hypotensive effect may have been caused by improved vascular endothelial function; nitric oxide produced by vascular endothelial cells induces relaxation of vascular smooth muscle cells.⁹

The limited number of subjects in this study led to a lack of accurate, statistically significant differences. However, a significant change on the MMSE was observed after the steam foot spa treatment. This was expected and led to an improvement in cognitive function caused by cholinergic nervous system activity. However, the effect of a steam foot spa was not observed on the behavioral and psychological symptoms of dementia. These results suggest that the significant change on MMSE following the steam foot spa treatments occurred because of vasodilatation by cholinergic neurons.

PC12 cells are derived from rat pheochromocytoma and have been used as an in vitro model of neuronal cells.²⁹ Due to the widespread use of PC12 cells under various culture conditions, spontaneous variants are often encountered. Drug-hypersensitive PC12m3 cells, which exhibit poor neurite outgrowth in response to nerve growth factor, were obtained. PC12m3 cells treated with nerve growth factor showed enhanced neurite outgrowth in response to various stimulants such as various drugs, calcimycin, and heat shock.³⁰ Three distinct mitogen-activated

protein kinase (MAPK) cascades have been identified in mammalian cells: extracellular signal-regulated kinase, c-Jun amino-terminal kinase (JNK), and p38 MAPK. A previous study demonstrated that JNK members are important players in neurodegenerative disorders, such as Alzheimer's disease and cellular stress responses.³¹ It has also been reported that p38 MAPK plays an important role protecting cardiac muscle cells through stress-induced apoptosis.³²

The neurite formation rate increased in the authors' heat-shock studies using a 44 $^{\circ}$ C 10-minute thermal stimulation, but only p38 MAPK activation was observed with no activation of JNK. However, p38 MAPK activity ended almost after 20 minutes of thermal stimulation. Moreover, JNK activity began 10 minutes after the heat stimulus. Approximately 95% of the cells underwent apoptosis after 20 minutes of JNK activity.³³

Fujita et al examined the effect of a dry sauna (60 $^{\circ}$ C for 15 minutes) on cardiac function improvement using a hamster heart failure model. The results suggested that signaling through p38 MAPK and reducing oxidative stress (4-hydroxy-2-nonenal) led to improved cardiac function.³⁴

The results suggest that p38 MAPK activity due to a heat stimulus reduced oxidative stress, which recovered cardiac function. However, using thermal stimulation for geriatric patients with cognitive impairment requires careful consideration of the temperature setting.

Conclusion

Steam foot spa treatment at an ideal setting of 42 $^{\circ}$ C for 20 minutes has the potential to improve cognitive function in elderly hospitalized patients with mild to moderate cognitive impairment. In addition, it may lead to improved cardiac function.

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Disclosure

The authors report no conflicts of interest in this work.

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