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RESEARCH NOTE

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A pilot study on the relationship between thermal habits, chronic inflammation, and arterial stiffness in young adults

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Abstract

Objective Atherosclerotic cardiovascular disease (ASCVD) progresses silently, highlighting the importance of early prevention. This pilot study aimed to examine the relationship between thermal habits—specifically hot-tub bathing—and biomarkers of chronic inflammation, as well as arterial stiffness in young adults.

Results Twenty-five participants were included: 9 males (mean age: 21.78 ± 2.05 years) and 16 females (mean age: 21.0 ± 0.97 years). We assessed hot bathing habits and measured plasma interleukin-6 (IL-6), high-sensitivity C-reactive protein (hsCRP), heat shock protein 70 (HSP70), and brachial-ankle pulse wave velocity (baPWV). IL-6 levels were significantly lower among habitual hot-tub bathers ($p = 0.04$ overall; $p = 0.018$ in females). In females, hsCRP tended to be lower with immersion bathing ($p = 0.08$). No significant differences were observed in hsCRP, HSP70, or baPWV in the overall, male, or female groups. In females, IL-6 negatively correlated with ABI ($\rho = -0.543$, $p = 0.03$), and baPWV negatively correlated with bathing duration ($\rho = -0.562$, $p = 0.045$). These findings suggest that habitual hot-tub bathing, a culturally embedded and easily implemented habit in Japan, may serve as a lifestyle intervention to reduce inflammation and support ASCVD prevention in young adults.

Keywords Habitual hot-tub bathing, Bathing habits, Thermal habits, Thermal stimulation, Fomentation, Atherosclerosis prevention, Chronic inflammation, Skeletal muscle, Interleukin-6 (IL-6)

Introduction

Among lifestyle-related diseases, atherosclerotic cardiovascular disease (ASCVD) is particularly concerned due to its asymptomatic progression in the early stages, which can lead to life-threatening conditions or severe disabilities. Therefore, ASCVD prevention is of paramount importance [1, 2]. Our previous research has explored the relationship between lifestyle habits, such as dietary patterns [3], exercise routines [4], and awareness of healthy habits [5], analyzing their effects on metabolic health indicators and cardiovascular risk factors. Although lifestyle modification is recognized as a critical factor in disease prevention, maintaining such changes over the long term remains challenging [6].

Some studies highlight skeletal muscle's role as a secretory organ, suggesting that thermal stimulation may alleviate chronic inflammation [7]. Our previous research indicates that thermal stimulation activates HSP70, exerting anti-insulin resistance, anti-apoptotic, and anti-inflammatory effects [8–10]. Mild chronic inflammation is a key driver of atherosclerosis [11, 12] and significantly contributes to ASCVD progression. Since ASCVD can develop silently and lead to severe health consequences,

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targeting inflammation is crucial for prevention [13]. Moreover, there is a rising concern about the increased risk of lifestyle-related diseases among younger populations due to poor lifestyle habits [14, 15]. Unhealthy dietary patterns, sedentary behavior, and irregular sleep cycles contribute to metabolic imbalances, which in turn promote chronic inflammation and arterial stiffness, key factors in ASCVD development. In a study involving Japanese young adults with an average age of 20.4 ± 0.6 years, impaired glucose tolerance was observed in approximately 40% of non-obese individuals [16]. Impaired glucose tolerance is a known factor contributing to the progression of atherosclerosis. Research on masked hypertension and arterial stiffness in young individuals [17] suggests that arterial stiffness can develop early in life. While lifestyle interventions have been reported to be effective for young people [18, 19], studies focusing on lifestyle modification and atherosclerosis in this demographic remain limited. Furthermore, skeletal muscle responses to exercise and thermal stimulation may differ between older and younger populations. Our research investigates the potential benefits of thermal stimulation on skeletal muscle, alongside dietary and exercise-based interventions, to enhance ASCVD prevention [8, 9, 20]. These studies have provided foundational insights into how lifestyle modifications can influence ASCVD prevention, forming the basis for our current investigation into thermal stimulation.

Based on these considerations, this study targeted young adults with the goal of contributing to effective ASCVD prevention through bathing habits in the future. Selecting young adults without ASCVD allows for a clearer evaluation of lifestyle influences. Furthermore, young individuals, whose lifestyles are not yet fixed, may benefit from early healthy habits for long-term health maintenance [21]. This preliminary study aims to elucidate the relationships between chronic inflammation-related proteins, arterial stiffness, and thermal stimulation habits in young adults. By examining these relationships, we seek to contribute to the development of non-invasive, lifestyle-based intervention strategies for the early prevention of ASCVD.

Main text

Methods

Participants in the study were recruited via public notices. Eligible participants were those without any underlying metabolic diseases. The study included 25 participants: 9 males (mean age: 21.78 ± 2.05 years) and 16 females (mean age: 21.0 ± 0.97 years). The average body mass index (BMI) was 22.92 ± 1.94 for males and 20.11 ± 2.68 for females (Table 1).

Table 1 Baseline characteristics

	Female (average ± SD)	Male
N	16	9
Age (years)	21.0 ± 0.97	21.78 ± 2.05
Height (cm)	159.48 ± 6.12	169.11 ± 4.26
Body mass (kg)	52.474 ± 8.3	65.67 ± 6.86
BMI (kg/m^2)	20.11 ± 2.68	22.92 ± 1.94

Each participant underwent a structured interview based on a self-administered questionnaire to assess thermal habits, along with measurements of arterial stiffness and plasma chronic inflammation-related proteins. The questionnaire was designed to evaluate participants' thermal habits and bathing habits. The questionnaire was tested by a small number of volunteers to see if they could complete it. The questionnaire included questions on bathing habits (immersion bathing vs. showering), bathtub water temperature and hot-tub bathing duration (time spent immersed in the bath), use of thermal devices (including types), foot baths, hot spring visits, and experience with thermal therapy. Based on the responses, participants were additionally interviewed regarding the situations in which they used thermal therapy devices.

Arterial stiffness was assessed using a blood pressure pulse wave analysis device (HBP-8000, OMRON HEALTHCARE Co., Ltd.) to measure brachial-ankle pulse wave velocity (baPWV). baPWV is widely used as a simple and non-invasive method to assess arterial stiffness by reflecting arterial wall elasticity.

For the measurement of chronic inflammation-related proteins (HSP70, hsCRP, IL-6), blood samples were collected from all participants. The collected blood samples were immediately centrifuged to separate plasma and stored at −40 °C until analysis. Before measurement, samples were thawed and analyzed immediately. Plasma levels of HSP70, hsCRP, and IL-6 were quantified using enzyme-linked immunosorbent assay (ELISA) with the following kits, according to the manufacturers' protocols: HSP70: HSP70 ELISA Kit (StressMarq Biosciences INC), hsCRP: hsCRP ELISA RUO (DRG Instruments GmbH), IL-6: Human IL-6 Immunoassay (Quantikine). All plasma samples were measured in duplicate, and the mean value of duplicate wells was used for analysis. To ensure measurement accuracy, appropriate controls and standard curves were set following the manufacturers' protocols.

Collected data were statistically analyzed using JMP Pro 17.0.0. For comparisons between two groups, the Mann–Whitney U test, a non-parametric test, was used. Spearman's rank correlation coefficient, a non-parametric correlation test, was applied to analyze relationships between two continuous variables.

This study was conducted with the approval of the Research Ethics Committee of Aino University (Approval No. 2021-012).

Results

The association between hot-tub bathing habits and chronic inflammation-related proteins, as well as arterial stiffness indicators, was examined in a sample of N = 25 (9 males and 16 females). Seventeen participants had a daily habit of bathing in the hot tub. Nineteen participants regularly used hot springs, while five participants used thermal devices in their daily lives. No participants had experience with thermal therapy or practiced foot baths at home.

Plasma IL-6 levels were significantly lower in individuals with a habit of immersion hot tub bathing in the overall analysis ($p = 0.04$). When analyzed separately by sex, no significant difference was observed in males ($p = 0.38$). However, in females, IL-6 levels were significantly lower in those with an immersion hot tub bathing habit ($p = 0.018$). No significant differences were observed in plasma hsCRP levels in the overall, male, or female groups ($p > 0.05$). However, in females, hsCRP tended to be lower in the immersion hot -tub bathing group, though the difference did not reach statistical significance ($p = 0.08$). Similarly, no significant differences in plasma HSP70 concentrations were observed in any group ($p > 0.05$). No significant associations were found between baPWV and blood chronic inflammation-related protein concentrations in the overall, male, or female analyses ($p > 0.05$) (Table 2).

Overall, a positive correlation was observed between bath duration and baPWV. Additionally, a negative correlation trend was noted between IL-6 levels and bath duration ($\rho = -0.412$, $p = 0.1$), while a significant positive correlation was found between bath duration and baPWV ($\rho = 0.506$, $p = 0.038$). In the male-specific analysis, a significant correlation was observed between HSP70 and ABI ($\rho = -0.795$, $p = 0.01$), as well as between HSP70 and hot tub bathing temperature ($\rho = 0.974$, $p = 0.00$). In females, IL-6 was significantly correlated with ABI ($\rho = -0.543$, $p = 0.03$), and baPWV showed a significant negative correlation with hot tub bathing duration ($\rho = -0.5616$, $p = 0.045$). No other significant correlations were observed. (Table 3). The results of the

Table 2 Association between hot tub bathing habits and chronic inflammation-related proteins and arterial stiffness

Variable	Bathing habits growp	Overall (N = 25)		Males (N = 9)		Females (N = 16)	
			p-value	Median (IQR)	*p-value*	Median (IQR)	*p-value*
IL-6 (pg/ml)	Habit	30.98 (29.81–34.73)	0.04**	30.06 (30.06–30.81)	0.38	32.06 (29.79–34.85)	0.018**
	No habit	34.31 (32.83–42.33)		32.35 (31.06–33.66)		45.52 (37.83–55.69)	
hsCRP (ng/ml)	Habit	1.19 (0.56–2.06)	0.15	1.19 (1.00–1.36)	0.54	1.23 (0.44–2.11)	0.08*
	No habit	0.58 (0.35 to + 1.00)		0.89 (0.63–1.63)		0.35 (0.33–0.51)	
HSP70 (µg/ml)	Habit	4.60 (4.28–5.15)	0.22	4.58 (4.28–4.6)	0.27	4.84 (4.36–5.76)	0.5
	No habit	1.19 (4.50–10.97)		6.83 (4.5–11.85)		6.06 (5.10–8.88)	
baPWV (cm/s)	Habit	1000.0 (932.25–1095.5)	0.15	1163.5 (1095.5–1169.5)	0.54	947.0 (925.31–1017.44)	0.67
	No habit	1142.75 (1016.31–1199.25)		1179.38 (1109.5–1245.19)		1039.38 (913.5–1163.81)	

The group with a habit of immersion bathing showed significantly lower plasma IL-6 levels in the overall analysis ($p = 0.04$) and in females ($p = 0.018$). On the other hand, no significant differences were observed in plasma hsCRP, HSP70 concentrations, or baPWV between the two groups. Comparison of the means was analyzed using the Mann–Whitney U test. ** $p < 0.05$, *$p < 0.1$

Table 3 Significant bivariate relationships between chronic inflammation-related proteins, arteriosclerosis, and bathing-related factors in overall, male, and female participants

Variable pair	Overall (ρ, p-value)	Male (ρ, p-value)	Female (ρ, p-value)
HSP70 vs ABI	−0.2799, p = 0.18	−0.7950, p = 0.01**	−0.0177, p = 0.95
HSP70 vs bathing temperature	−0.0471, p = 0.85	0.9747, p = 0.00**	−0.3132, p = 0.30
IL-6 vs ABI	−0.2464, p = 0.24	0.1192, p = 0.76	−0.5432, p = 0.03**
baPWV vs bathing duration	0.5055, p = 0.038**	–	−0.3232, p = 0.28
baPWV vs bathing temperature	−0.2964, p = 0.23	−0.3591, p = 0.55	−0.5616, p = 0.045**
IL-6 vs bathing duration	−0.41229, p = 0.1*	–	−0.166, p = 0.5879

The relationship between the two continuous variables was evaluated using Spearman's rank correlation coefficient. **$p < 0.05$; *$p < 0.1$

bivariate analysis for all variables are provided in the supplementary file (Table 4).

Among female participants, those who regularly used hot springs had a significantly higher BMI (21.12 ± 2.63) compared to those without a hot spring habit (17.89 ± 0.87, p = 0.001). Additionally, the group that regularly used hot springs tended to have lower baPWV levels (946.2 cm/s ± 74.8) compared to the group that did not use hot springs (1074.7 cm/s ± 118.6) (p = 0.089). However, most participants reported visiting hot springs only once every few months, suggesting that hot spring use was not a substitute for habitual home bathing. In male participants, no variables showed a significant association with hot spring use.

The use of thermal devices was not observed among male participants. Therefore, the analysis was conducted only for female participants. However, in this study, no statistically significant differences were found between the use of thermal devices and chronic inflammation-related proteins or arterial stiffness. Future studies should increase the sample size and continue observations.

Discussion

In this study, habitual hot-tub bathing was associated with lower levels of IL-6 in overall and female, a protein related to chronic inflammation (Table 2). Additionally, a longer hot-tub bathing duration tended to be negatively correlated with lower IL-6 levels in overall (Table 3), positive correlation was observed between hot-tub bathing temperature and plasma HSP70 levels in male (Table 3). These results suggest that the presence of a hot-tub bathing habit and specific bathing conditions may influence chronic inflammation-related proteins. However, this study cannot explicitly establish a causal relationship; it can only suggest a possible association. Therefore, it is worth continuing to observe in future research.

IL-6 is an inflammatory cytokine that also impacts chronic inflammation underlying atherosclerosis. In individuals with advanced atherosclerosis, blood inflammatory markers such as CRP and IL-6 are elevated [22]. However, IL-6 is secreted by skeletal muscle during thermal stimulation or exercise acts as a myokine with anti-inflammatory effects and reduces insulin resistance [23, 24]. No literature was found that directly mentions the possibility that habitual thermal therapy or habitual hot tub bathing, particularly through its thermal effects, influences skeletal muscles and IL-6 secretion.

The impact of hot-tub bathing on IL-6 levels in the context of chronic inflammation and atherosclerosis remains debated. While some studies suggest that elevated IL-6 levels are beneficial [25], others indicate that lower levels are preferable [26, 27]. For instance, Oyama et al. [26] reported that a 2-week hot spring therapy in heart failure patients significantly reduced inflammatory markers, including hsCRP, tumor necrosis factor-α (TNF-α), and IL-6. Similarly, Yasuda reported that rehabilitation and hot spring bathing reduced IL-6 levels in patients with rheumatoid arthritis [28]. Compared to populations in the United States and Europe, Japanese individuals have lower blood levels of IL-6 and CRP [29], suggesting a possible relationship with the Japanese diet and bathing frequency [27]. These findings highlight the potential anti-inflammatory benefits of bathing habits. Previous studies have similarly reported changes in IL-6 but not in hsCRP [25, 27]. Although our study cannot draw definitive conclusions due to the small sample size, a positive correlation was observed between hot tub bathing temperature and blood HSP70 levels in males, suggesting that bathing conditions, such as temperature, may influence HSP70 levels. Itoh et al. have also reported that HSP70 activation varies depending on bathing frequency and temperature [30]. Future studies should further investigate bathing conditions, including temperature and duration, as well as the persistence of HSP70 effects. The behavior of chronic inflammatory proteins varies by factor, and these mechanisms remain unclear, necessitating further investigation [25, 27].

This study focused on younger participants. However, previous research by Yamashiro et al. [25] found differences in IL-6 responses to bathing between older and younger individuals [25, 27]. They suggested that age-related changes in thermoregulation and muscle fibers affect IL-6 secretion from skeletal muscles [25]. Also, incorporating thermal habits may activate skeletal muscles [31]. IL-6 is produced by type II muscle fibers, which decline in relative volume with age in men [32]. Consequently, the amount of IL-6 produced by type II fibers may decrease in older individuals [25]. This is an important consideration when selecting participants to study the effects of bathing on atherosclerosis.

Regarding baPWV, a significant positive correlation with hot tub bathing duration was observed in the analysis restricted to overall participants (Table 3). Additionally, in females, a significant negative correlation was found between baPWV and bathing temperature (Table 3). Bathing duration may potentially influence chronic inflammation and arterial stiffness; however, there are currently no available studies reporting on this relationship. Therefore, further research is needed to conduct a more detailed investigation of bathing habits and examine how specific conditions, such as hot bath duration and temperature, affect chronic inflammation and arterial stiffness.

From an ASCVD prevention perspective, while definitive conclusions about bathing conditions remain elusive, factors such as bathing duration and temperature may influence chronic inflammation and arterial stiffness. Kubo et al. [33] reported that individuals with higher BMI tended to bathe longer, likely due to differences in body warming time. Future studies should account for variables such as body fat percentage, muscle mass, temperature sensitivity, BMI, metabolic rate, heat dissipation, lifestyle, cultural background, stress levels, relaxation, and fatigue recovery. Adequate sample sizes are essential to validate these relationships and establish effective bathing practices.

Regarding hot spring use, female participants who used hot springs had a significantly higher BMI compared to those without a hot spring habit and tended to have lower baPWV levels. Most participants used hot springs only once every few months, rather than as a replacement for habitual hot-tub bathing. A cohort study by Miyata et al. [34] found that daily bathing was associated with lower cardio-Ankle Vascular Index (CAVI), an arterial stiffness indicator, but weekly hot spring use had no effect. Similarly, Kagami et al. [35] reported no effect of weak radioactive hot springs on arterial stiffness. These findings suggest that regular home bathing may be more important for ASCVD prevention than occasional hot spring use. Habitual hot-tub bathing has been shown to tend to suppress the progression of baPWV and maximum carotid intima-media thickness (IMT), suggesting that regular bathing may have beneficial effects on arterial stiffness and central hemodynamics [36].

In the case of sauna bathing, it has been reported that higher frequency is associated with lower levels of inflammatory markers such as hsCRP, fibrinogen, and white blood cell count [37, 38]. Finnish-style sauna bathing acutely improves brachial artery flow-mediated dilation (FMD) in middle-aged and older adults with stable coronary artery disease (CAD), indicating an improvement in vascular endothelial function [39]. Based on these findings, habitual hot-tub bathing is predicted to influence the behavior of chronic inflammation-related proteins in the bloodstream. However, the details remain unclear, and further research is needed.

Limitations

This study has several limitations, including a relatively small sample size. As a pilot study, the statistical power and representativeness of the findings are limited. Additionally, dietary intake and physical activity were not strictly controlled in this study, but future research should aim to regulate these factors to enhance the reliability of the results.

To validate these preliminary findings and derive more generalizable insights, future studies should include a larger and more diverse population. Furthermore, since participants voluntarily responded to public notices, they may have had a preexisting interest in thermal habits, potentially introducing selection bias. Another limitation is that this study relied on self-reported surveys, which prevented direct observation and may have affected data accuracy.

Future research should incorporate a broader range of individuals to assess the impact of hot-tub bathing on ASCVD prevention across different lifestyles and cultural backgrounds. Additionally, since this study focused solely on younger individuals, age-group comparisons were not possible. To fully understand the effectiveness of bathing habits in younger populations, future studies should include comparisons with other age groups. Moreover, extended longitudinal studies are necessary to better evaluate the long-term effects of bathing habits.

Conclusion

In conclusion, lifestyle interventions, particularly in younger individuals, may be effective in ASCVD prevention. Habitual hot-tub bathing is easy to adopt in Japan and may help optimize skeletal muscle function without the burden of dietary restrictions or exercise.

Abbreviations

ASCVD	Atherosclerotic cardiovascular disease
baPWV	Brachial-ankle pulse wave velocity
BMI	Body mass index
CAVI	Cardio-ankle vascular index
ELISA	Enzyme-linked immunosorbent assay
HSP70	Heat shock protein 70
hsCRP	High-sensitivity C-reactive protein
IL-6	Interleukin-6
TNF-α	Tumor necrosis factor-alpha
CAD	Coronary artery disease
FMD	Flow-mediated dilation
IMT	Intima-media thickness

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13104-025-07236-w.

Supplementary material 1.

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Author contributions

Authors' Contributions Masayo Nagai contributed to the study design, data collection, data analysis, manuscript drafting and secure funding. Akiko Tanaka contributed to data analysis, critically reviewed the final manuscript. All authors read and approved of the final manuscript.

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Availability of data and materials
Availability of Data and Materials The datasets and materials used during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted with the approval of the Research Ethics Committee of Aino University (Approval No. 2021-012). All participants provided informed consent prior to participation. This study was conducted in accordance with the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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