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Sauna bathing and incident hypertension: a prospective cohort study

Running heading: sauna and hypertension

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Abstract

Background: Sauna bathing is associated with a reduced cardiovascular risk, but the mechanisms underlying this beneficial effect are not entirely understood. We aimed to assess the relationship between sauna bathing and risk of incident hypertension

Methods: Frequency of sauna bathing was ascertained using questionnaires in the Kuopio Ischemic Heart Disease Study, a prospective long-term cohort study conducted in Eastern Finland that comprised a population-based sample of 1621 men aged 42 to 60 years without hypertension at baseline. The incidence of hypertension was defined as a physician diagnosis of hypertension, systolic blood pressure (SBP) > 140mmHg, diastolic blood pressure (DBP) > 90mmHg, or use of antihypertensive medication.

Results: During a median follow-up of 24.7 years, 251 incident cases (15.5%) were recorded. In Cox regression analysis adjusted for baseline age, smoking, body mass index, and SBP; compared to participants reporting 1 sauna session per week, the hazard ratio for incident hypertension in participants reporting 2 to 3 sessions and 4 to 7 sessions was 0.76 (95% CI: 0.57 to 1.02) and 0.54 (0.32 to 0.91), respectively. The corresponding hazard ratios were similar after further adjustment for baseline glucose, creatinine, alcohol consumption, resting heart rate, family history of hypertension, socioeconomic status, and cardiorespiratory fitness: 0.83 (95% CI: 0.59 to 1.18) and 0.53 (0.28 to 0.98) respectively.

Conclusions: Regular sauna bathing is associated with reduced risk of hypertension, which may be the mechanism underlying the decreased cardiovascular risk associated with sauna use. Further epidemiological and experimental studies could help elucidate the effects of sauna bathing on cardiovascular function.

Introduction

Sauna bathing may have various health benefits including a reduced cardiovascular risk. We have previously shown that regular sauna bathing could be a protective factor against the development of cardiovascular diseases (CVDs).¹ Specifically, participants reporting four to seven sauna sessions per week had a markedly reduced risk of fatal CVD events compared to participants with one sauna session per week, independently of well-established risk factors as well as several other potential confounders. The underlying physiological mechanisms for this protective effect, however, are still unknown. Prior studies have shown that sauna bathing is associated with better cardiovascular function²⁻⁵ and produces positive short-term effects on systemic blood pressure,⁶ although the long-term effects of habitual sauna bathing on the risk of hypertension have not been previously investigated.

Tight control of blood pressure is a cornerstone in the prevention of CVDs. Recent studies have confirmed the importance of blood pressure reduction, suggesting additional cardiovascular benefits for systolic blood pressure (SBP) of less than 120mmHg as compared with less than 140mmHg.⁷ As sauna bathing produces acute vasodilation which leads to a significant drop in blood pressure,⁴ regular sauna bathing could potentially result in long-term reduction of blood pressure. This mechanism may further explain the protective effects of sauna bathing on the cardiovascular system. In this study, we aimed to investigate whether sauna bathing was associated with a reduced risk of incident hypertension using a long-term prospective cohort study comprising of apparently healthy middle-aged Finnish men without a history of hypertension at baseline.

Methods

Study population

The Kuopio Ischemic Heart Disease (KIHD) study was designed to investigate risk predictors for atherosclerotic cardiovascular outcomes in a population-based sample of men from Eastern Finland. Participants were a randomly selected sample of 3,433 men aged 42 to 60 years who resided in the town of Kuopio or its surrounding rural communities.⁸ Of those invited, 2682 (83%) participated in the study. Participants with baseline hypertension (n=811), reporting no regular sauna bathing (n=8) or with missing data on sauna (n=242) were excluded, leaving 1621 participants for the analyses. Prevalent hypertension at baseline was defined as physician diagnosis of hypertension, SBP > 140mmHg, diastolic blood pressure (DBP) > 90mmHg, or antihypertensive therapy. Men who participated (n =1621) were younger (age 52.9 years vs. 53.3 years, p=0.029) and their BMI (26.3 vs 27.8 kg/m², p<0.001), plasma glucose levels (4.7. vs 4.9 mmol/L, p<0.001), socioeconomic status (SES) (8.3 vs 8.6, p=0.002), proportion with a family history of hypertension (42.1 vs 57.4 %, p=0.001), alcohol consumption (69.7 vs 86.7 grams/week, p=0.002) and SBP (129.7 vs 141.0, p<0.001) were lower compared with men who were excluded (n=1061) in the final study analysis. Cardiorespiratory fitness (CRF) as assessed by maximal oxygen uptake (VO₂max) (31.7 vs. 27.8 ml/kg/minute, p<0.001) was higher among men included in the analyses. All other main variables including serum creatinine and lipid levels, smoking habits and resting heart rate did not differ statistically significantly.” Baseline examinations were conducted between March 1984 and December 1989. The study was approved by the research ethics committee of the University of Eastern Finland, Kuopio, Finland. Each participant gave written informed consent. This study was performed following the STROBE (STrengthening the Reporting of OBServational studies in Epidemiology) guidelines for reporting observational studies in epidemiology (**Appendix**).

Assessment of sauna bathing

The characteristics of typical sauna bathing have been previously reported.¹ Briefly, the recommended temperature for sauna is usually from 80°C to 100°C. The temperature in the sauna room was

measured using a thermometer located in the sauna room and was self-reported. Baseline sauna bathing habits were assessed by self-administrated questionnaires based on weekly sauna sessions, duration and temperature.¹ The questionnaires were checked by an experienced nurse at the time of baseline examination.

Assessment of risk factors

Covariates were assessed at baseline. A participant was defined as a smoker if he had ever smoked on a regular basis. Resting blood pressure was measured between 8:00 and 10:00 AM with a random-zero sphygmomanometer using a standardised protocol. After a supine rest of 5-minutes, blood pressure was measured three times in supine position, once in standing position, and twice in sitting position with 5-minute intervals, and the arithmetic mean of all available measurements was taken. The collection of blood specimens and the measurement of serum lipids, glucose and creatinine have been described-previously.^{1,9} Body mass index (BMI) was computed as the ratio of measured weight in kilograms to the square of measured height in meters. Alcohol consumption was assessed using the Nordic Alcohol Consumption Inventory.⁹ Socioeconomic status (SES) was assessed by self-administered questionnaires.^{1,9} Heart rate from the electrocardiogram was recorded at rest.⁹ Maximal oxygen uptake was used as a measure of CRF, which was defined as the highest value or the plateau of oxygen uptake^{10,11} during a standardized cycle testing protocol comprising an increase in the workload of 20 W per minute with the direct analyses of respiratory gases (Medical Graphics, St. Paul, Minnesota).

Ascertainment of incident hypertension

Incident hypertension was ascertained through record linkage to two sources: (i) the national hospital discharge registry, and (ii) the Social Insurance Institution of Finland register, which contains information on the reimbursement of expenses for antihypertensive medication. Hypertension was defined as a physician diagnosis of hypertension, SBP >140 mmHg, DBP >90 mmHg, or use of

antihypertensive medication (beta-blockers, calcium channel blockers, diuretics or ACE/angiotensinogen receptor antagonists). There were no losses to follow-up.

Statistical analysis

Differences in clinical characteristics according to incident hypertension events were examined using the analysis of variance and the chi-squared test, as appropriate. Descriptive data are presented as mean (standard deviation, SD) and number (percentage). Time-to-event analysis was conducted using Cox proportional hazards models to examine the association of sauna bathing with incident hypertension, after confirming assumptions of proportionality of hazards which was examined by plotting the hazard functions in different categories of risk factors over time. Participants were divided into three groups on the basis of the frequency of sauna bathing (1 time, 2-3 times, and 4-7 times per week). Three complete-case multivariable Cox models were progressively adjusted for baseline values of: age, smoking, BMI, and SBP (model 1); model 1 plus glucose, creatinine, alcohol consumption, and resting heart rate (model 2); model 2 plus family history of hypertension, socioeconomic status, and cardiorespiratory fitness (model 3). These confounders were selected based on their previously established role as risk factors for hypertension and CVD, evidence from previous research, or their potential as confounders based on known associations with hypertension and observed associations with sauna frequency using the available data. The linearity assumption was satisfied for all continuous variables and it was assessed with Martingale residuals for each continuous variable against survival time. P-value < 0.05 was considered statistically significant. Statistical analyses were performed using Stata version 14.1 (Stata Corp, College Station, Texas).

Results

Baseline characteristics

The mean (SD) age of included subjects was 52.9 (5.2) years. Two-thirds of participants reported 2 to 3 sauna sessions per week while 9% of participants reported 4 to 7 sessions per week. An average duration of a single sauna session was 14.4 (7.8, range 2-90) minutes. Comparing men using sauna

only once per week with those with at least two sauna sessions per week, the mean duration of a single sauna session was 14.4 (8.5) vs. 14.5 (7.6) minutes ($p=0.779$) and the mean temperature of sauna was 80.9 (10.9) vs. 78.3 (8.9) °C ($p<0.001$). The number of participants without regular use of sauna was very low (12 men, 8 without hypertension). With the exception of BMI and serum creatinine, other baseline characteristics were not significantly different between men who developed hypertension during follow-up and those who did not develop hypertension (**Table 1**). In this male population without prevalent hypertension at baseline, mean SBP was 130 (15) mmHg and DBP was 84 (10) mmHg, respectively.

Sauna bathing and risk of hypertension

The average follow-up time to diagnosis of hypertension or the end of follow-up was 22.0 years (median 24.7 years, interquartile range 18.4-26.9 years). The number (percentage) of new cases of hypertension was 66 (26.3%), 166 (66.1%), and 19 (7.6%) according to the three groups of frequency of sauna bathing (1, 2-3 and 4-7 times per week, respectively; **Table 1**). The corresponding numbers for non-incident cases were 323 (23.6%), 921 (67.2%), and 126 (9.2%). On adjustment for age, smoking, BMI, and SBP (model 1), the HR for hypertension was 0.76 (95% confidence interval (CI): 0.57 to 1.02) for 2-3 sauna bathing sessions per week and 0.54 (0.32 to 0.91) for 4-7 sauna bathing sessions per week compared with men reporting 1 sauna bathing session per week (**Figure 1**). Further adjustment for other risk factors (model 2 and 3) did not materially change the estimates; compared with one session, 2-3 and 4-7 sauna sessions per week were respectively associated with HRs of 0.78 (0.56 to 1.09) and 0.48 (0.26 to 0.87) for model 2 and 0.83 (0.59 to 1.18) and 0.53 (0.28 to 0.98) for model 3 (**Figure 1**).

Discussion

In this population-based cohort study of Finnish middle-aged men without a history of hypertension at baseline, we found that higher frequency of sauna bathing is independently associated with a lower risk of incident hypertension in a dose-response manner. These findings could help elucidate the

potential mechanisms underlying the long-term reduction of cardiovascular mortality associated with sauna bathing.

Clinical Implications

Sauna bathing is associated with beneficial physiologic changes, most notably reduction in resting blood pressure. During a hot sauna session, the blood volume to the periphery and skin is increased and the heart rate increases so that the blood pressure in internal organs can be maintained. In patients with slightly elevated blood pressure, a single sauna session produces positive effects on systemic blood pressure, including 24-hour blood pressure levels.¹² Heat therapy such as hot water immersion is associated with several health benefits including lower levels of resting blood pressure potentially reducing the risk of cardiovascular diseases CVD.¹³ However, in this study, sauna bathing was employed as the mode of heat therapy. Further studies are needed to show if other kinds of heat therapies can produce similar risk reductions in hypertension and CVD as recent epidemiological evidence is based on traditional Finnish sauna use only. Consistent with these findings, there is some evidence indicating that blood pressure levels are lower among those who live in warm conditions based on ambient temperatures.¹⁴

Mechanisms

Regular sauna bathing may have beneficial effects on the cardiovascular system such as blood pressure reduction via a number of potential mechanisms. Firstly, repeated sauna sessions improve vascular endothelial function in patients at high CVD risk, suggesting a beneficial role of thermal therapy on the endothelium.^{12,15-16} Secondly, sauna bathing also affects the autonomic nervous system. A typical Finnish sauna session is indeed characterized by warming up in the sauna with subsequent cooling and relaxation; this can positively modulate the autonomic system and may further explain the effects on blood pressure reduction.^{18,19} Thirdly, heart rate may increase up to 100-150 beats per minute during sauna bathing session^{4,20-23} which increases vasodilatation and improves function of the vasculature; these are the same benefits that are associated with low and moderate intensity physical

exercise training. However, there is no active function of skeletal muscles during sauna bathing, which is in contrast to the training response experienced during physical exercise. Sauna bathing leads to skin sweating-induced body fluid loss, which is a physiological response to hot temperature.²⁴ Taken together, these experimental findings suggest a biological plausibility to the inverse association between sauna and risk of hypertension. Our findings also suggest that the protective effect of sauna bathing on CVD may be via the blood pressure lowering effects of regular sauna bathing. Appropriate interventional studies in animal models or clinical trials are needed to confirm any causal associations.

Limitations

Our findings on the association between sauna bathing and the risk of hypertension cannot be directly applied to other types of saunas, all kind of steam rooms or hot tubs; which may operate at a lower temperature than a typical Finnish sauna. Although we adjusted our analyses for many other potential confounders and risk factors for future hypertension to test the robustness of our results, the potential for residual confounding cannot be entirely eliminated. On the other hand, the results were carefully adjusted for confounders in the association with hypertension, such as BMI, smoking, cardiorespiratory fitness, alcohol intake and SES. Notably, majority of Finnish people use sauna regularly and access to sauna is not limited by socioeconomic background or other reasons.^{1,17} The view of sauna as an indicator of SES is indeed stronger and more common in non-Finnish cultures than in Finland. Although we accounted for SES, it is not possible to exclude completely that sauna is not an indicator of economic, familial, or working traits. These results could in part be explained by divergent educational background, economic facilities, family engagement, professional commitment, or "attention" to lifestyle among people reporting different sauna use. In the interpretations of our findings, these aspects should be considered along with well-known beneficial physiological changes of the cardiovascular function. In this study, it was not possible to correct for regression dilution bias which may have underestimated the associations demonstrated, as we had only a one-time questionnaire-based assessment of sauna bathing during a typical week. Sauna bathing habits may have changed during follow-up due to probable changes in other health habits of participants

occurring over the long period of observation. It is unlikely that this would have any considerable effect on the main findings, given that sauna bathing is a tradition and embedded in the culture of the Finnish people. Lastly, although sauna bathing seems to be safe and most people can tolerate a typical relatively hot and dry sauna (including patients with previous CVD),⁵ it should be noted that participants included in this study had resting blood pressure ranging within normal limits and were not on antihypertensive medication. Individuals with known orthostatic hypotension should be cautious because of a rapid drop in blood pressure, which may occur just after warm sauna bathing.^{2,25}

Conclusions

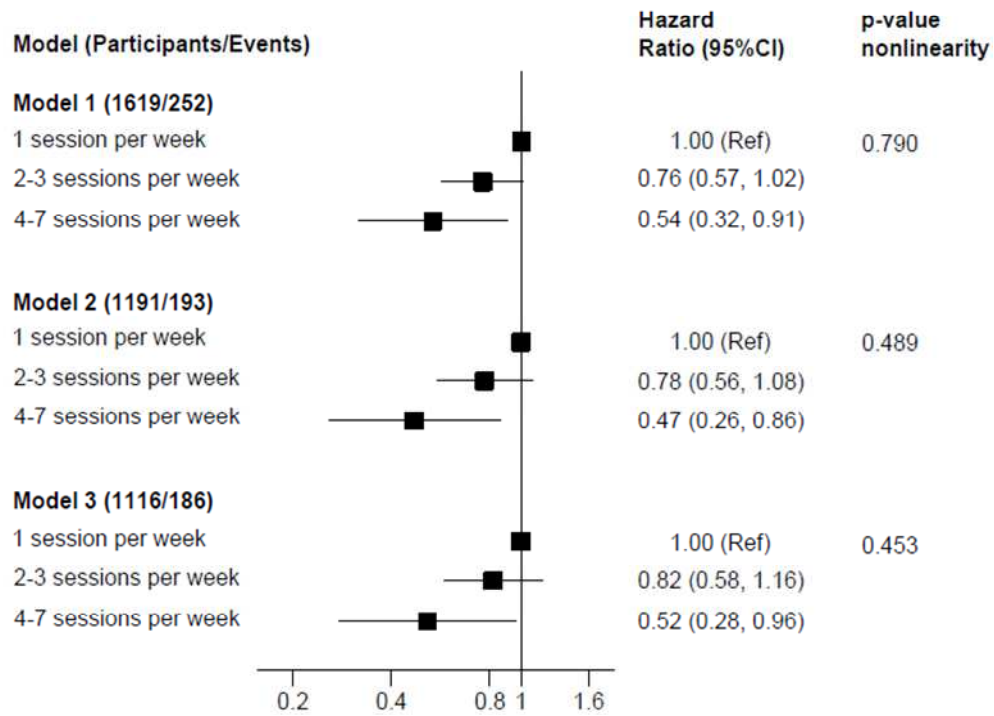
This study provides prospective evidence that sauna bathing is inversely associated with the risk of hypertension in the general male population and suggests a potential mechanism underlying the long-term cardiovascular beneficial effects of sauna bathing. Our current results suggest that sauna bathing, an activity that promotes relaxation and well-being, may be a recommendable habit in the prevention of future hypertension. Further studies are needed to confirm our results in different population settings, including women, and among those who are not familiar to regular sauna bathing.

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Figure legends

Figure 1: Hazard ratios for incident hypertension



Model 1: Adjusted for age, smoking, BMI, baseline systolic blood pressure

Model 2: Model 1 + Glucose, creatinine, alcohol consumption, resting heart rate

Model 3: Model 2 + Family history of hypertension, socioeconomic status, cardiorespiratory fitness

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Table 1: Baseline characteristics of study participants

Variable	Incident Hypertension		Total (N=1,621)	p-value Yes vs No
	Yes (N=251)	No (N=1,370)		
Age (years)	53.4 ± 4.9	52.8 ± 5.3	52.9 ± 5.2	0.106
Body mass index (kg/m ²)	27.3 ± 3.7	26.1 ± 3.2	26.3 ± 3.4	<0.001
Plasma fasting glucose (mmol/l)	4.7 ± 1.1	4.7 ± 1.1	4.7 ± 1.1	0.386
Serum creatinine (µmol/l)	90 ± 12	89 ± 13	89 ± 13	0.042
Heart rate (bpm)	63 ± 11	62 ± 10	62 ± 11	0.072
Socioeconomic status*	8.6 ± 4.1	8.3 ± 4.3	8.3 ± 4.3	0.272
VO ₂ max (ml/min)†	2,399 ± 596	2,479 ± 653	2,466 ± 644	0.083
Current/former smoking (Yes)	74 (29.5)	453 (33.1)	527 (32.6)	0.259
Family history hypertension (Yes)	117 (46.6)	567 (41.4)	684 (42.2)	0.123
Alcohol consumption (g/week)				
0	32 (12.8)	184 (13.4)	216 (13.3)	0.326
0-19	62 (24.7)	406 (29.7)	468 (28.9)	-
20-76	82 (32.3)	386 (28.2)	468 (28.9)	-
≥77	75 (29.9)	392 (28.6)	467 (28.8)	-
Sauna sessions per week				
1	66 (26.3)	323 (23.6)	389 (24.0)	0.517
2-3	166 (66.1)	921 (67.2)	1,087 (67.1)	-
4-7	19 (7.6)	126 (9.2)	145 (8.9)	-

Data are reported as mean ± standard deviation or number (%)

* Socio-economic status is a summary index that combines measures of income, education, occupation, occupational prestige, material standard of living, and housing conditions, all of which were assessed with self-reported questionnaires

† Cardiorespiratory fitness defined as the highest value for or the plateau of oxygen uptake during exercise testing