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Original Research

Finnish sauna bathing does not increase or decrease the risk of cancer in men: A prospective cohort study

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Cohort study

Abstract ***Introduction:*** Evidence suggests that heat therapy can be used to prevent and treat cancer; anecdotal reports suggest passive heat therapies may increase cancer risk. Finnish sauna bathing has been linked to a reduced risk of chronic diseases, but its association with cancer risk is unknown. We aimed to assess the prospective association between frequency of sauna bathing and the risk of all-cause and site-specific cancers using the Kuopio Ischemic Heart Disease prospective cohort.

Methods: Baseline sauna bathing habits were assessed in 2173 men aged 42–61 years with no history of cancer. Hazard ratios (HRs) with 95% confidence intervals (CIs) for cancer were calculated using Cox proportional hazard models. We corrected for within-person variability in sauna bathing habits using data from repeat assessments taken 11 years apart.

Results: During a median follow-up of 24.3 years, 588 (27.1%) all-cause cancer cases were recorded. The age-adjusted regression dilution ratio of sauna bathing frequency was 0.69 (0.62–0.76). In multivariable-adjusted analyses, the HRs (95% CIs) of all-cause cancer were 0.92 (0.76–1.11) and 0.92 (0.66–1.27) for men who had 2-3 and ≥4 sauna sessions per week, respectively, compared with men who had ≤1 sauna session per week. The non-significant

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findings were consistent for prostate, gastrointestinal and lung cancers on multivariate adjustment.
Conclusion: Frequent Finnish sauna bathing is not associated with the risk of cancer in a middle-aged male Caucasian population. Further studies are required to confirm or refute these findings, particularly in women and other age groups.

1. Introduction

Cancer is a leading cause of mortality globally and a global health burden. As populations age and adopt lifestyle behaviours that increase cancer risk, cancer incidence and deaths are expected to grow proportionately. Established risk factors for all-sites cancer generally include race, age, family history and environmental factors such as tobacco and alcohol use, diet, physical inactivity, excess body weight and hormonal changes [1]. Prostate cancer is the second most frequently diagnosed cancer among males globally, and it is commonly associated with factors related to economic development such as excess body weight, physical inactivity and high consumption of animal fats [2]. Lung cancers are primarily shaped by tobacco smoking [3]; they can also be caused by exposure to environmental pollution [4]. Important risk factors for gastrointestinal cancers such as esophageal, stomach, colon, rectum and liver cancers include smoking, excessive alcohol consumption, diets high in red and processed meat and chronic infections with hepatitis viruses [1]. Though these factors explain a large proportion of cancer risk, its pathogenesis is still not fully established as several other potential risk factors appear to be involved. There is therefore a need to critically evaluate putative risk factors that may increase our knowledge of cancer development, which will help develop preventive and management strategies. Hyperthermia (a type of treatment in which body tissue is exposed to high temperatures) has commonly been used as an adjunctive therapy in combination with established cancer treatments such as radiotherapy and chemotherapy [5–7]. Treatment with hyperthermia can be local, regional or whole-body, and this depends on the extent of the area being treated [7]. In local hyperthermia, heat is applied to a small area such as a brain tumour or tumours below the skin or within body cavities such as the oesophagus or rectum. Regional hyperthermia is used for large body areas such as a limb, organ or a body cavity [7]. Whole-body hyperthermia is commonly used to treat metastatic cancer that has spread throughout the body [5]. Anecdotal evidence suggests that heat therapy, particularly from infrared saunas, may play a role in preventing or reversing cancer [8]. Plausible pathways proposed to underlie this effect include inhibition of cancer cell growth, decongestion of internal organs, removal of chemical toxins and heavy metals, enhancement of the immune system, production of heat shock proteins and enhancing oxygenation [8–10]. Finnish sauna bathing is a passive heat therapy which has traditionally been used for the purposes of pleasure, wellness and relaxation [11]. Beyond these uses, Finnish sauna bathing has been linked with several health benefits, which include reduction in the risk of several chronic diseases as well as mortality [11]. Given the overall evidence on the potential role of heat therapy in reducing or reversing cancer risk, we hypothesized that regular sauna bathing may be linked to a reduced risk of cancer. Furthermore, in contrast to potential beneficial effects of sauna exposure on cancer risk, some reports have suggested that infrared saunas may promote cancer risk [12]. In this context, using a population-based prospective cohort comprising 2173 middle-aged Caucasian men, we aimed to assess the association of frequency of Finnish sauna bathing with the risk of all-cause and site-specific cancers.

2. Methods

This study was conducted according to STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines for reporting observational studies in epidemiology (Appendix) [13]. The study population comprised participants in the Kuopio Ischemic Heart Disease risk factor study, a prospective population-based cohort study conducted in eastern Finland. The study design, recruitment of participants and assessment of risk markers have been described in detail previously [14]. Study participants were a representative sample of men aged 42–61 years living in the city of Kuopio and its surrounding rural communities in eastern Finland at the time of baseline examinations, which were performed between March 1984 and December 1989. Sauna bathing habits were assessed by self-administered questionnaires and cross-checked by experienced nurses [15,16]. The assessment of frequency and duration of sauna sessions represented an average sauna use during the week. Participants were classified into three groups based on the frequency of sauna bathing ($\leq$1, 2–3 and $\geq$4 sessions per week) [15,16]. Owing to lifestyle changes, ageing, measurement errors and recall bias in exposure estimation in prospective cohort studies, analysis using only baseline measurements of an exposure could underestimate the true strength of any association between exposure and outcome (i.e. "regression dilution bias" [17]). To clarify this issue, using repeat assessments of sauna bathing habits taken 11 years apart in a random subset of 722 men, we estimated and corrected for the effect of this regression dilution bias by calculating an age-adjusted regression dilution ratio (RDR). The RDR assumes that the "usual levels" of sauna bathing habits represent the true long-term exposure of sauna bathing habits on cancer risk. The primary outcome was first-time cases of all-cause cancer that occurred from study enrolment through to 2013. Secondary outcomes were site-specific cancers: prostate; gastrointestinal (comprising esophageal, stomach, intestinal, colon, rectal, pancreatic and liver); and lung cancer. All cancer cases were derived from the population-based Finnish Cancer Registry (FCR). The coverage of FCR is complete and there were no losses to follow-up [18]. The present analysis is based on a cohort of 2173 cancer-free men at baseline, with complete information on sauna bathing habits, relevant confounders and cancer outcomes. The study was approved by the Research Ethics Committee of the University of Eastern Finland, and each participant was provided written informed consent. All study procedures were conducted according to the Declaration of Helsinki. Multivariable hazard ratios (HRs) with 95% confidence intervals (CIs) for cancer were calculated using Cox proportional hazard models. Statistical analyses used Stata version 15 (Stata Corp, College Station, Texas, USA).

3. Results

The baseline characteristics of study participants overall and by categories of the frequency of sauna sessions per week are presented in Table 1. The overall mean [standard deviation (SD)] age and body mass index (BMI) of study subjects at baseline were 53 (5) years and 26.9 (3.5) kg/m^2, respectively. During a median (interquartile range [IQR]) follow-up of 24.3 (16.0–26.7) years, 588 all-cause cancer cases (annual rate 12.9/1000 person-years at risk; 95% CI: 11.9 to 14.0) occurred. There were 215 prostate, 130 gastrointestinal and 92 lung cancer cases. In analysis adjusted for age, the HRs (95% CIs) of all-cause cancer were 0.87 (0.73–1.05) and 0.87 (0.63–1.20) for men who had 2-3 and ≥4 sauna sessions per week, respectively, compared with men who had ≤ 1 sauna session per week. Following further adjustment for BMI, smoking status, history of diabetes, fasting glucose, triglycerides, total cholesterol, alcohol consumption, total energy intake, socioeconomic status, physical activity and high-sensitivity C-reactive protein, the corresponding HRs (95% CIs) were 0.92 (0.76–1.11) and 0.92 (0.66–1.27), respectively (Table 2). The overall age-adjusted RDR of sauna bathing frequency was 0.69 (95% CI: 0.62 to 0.76), which suggests that using only

Table 1
Baseline participant characteristics overall and by categories of frequency of Finnish sauna bathing.

Characteristics	Overall (N = 2173) Mean (SD) or median (IQR) or n (%)	≤1 session/week (N = 563) Mean (SD) or median (IQR) or n (%)	2-3 sessions/week (N = 1417) Mean (SD) or median (IQR) or n (%)	≥4 sessions/week (N = 193) Mean (SD) or median (IQR) or n (%)
Frequency of sauna bathing (times/week)	2 (1–2)	1 (1–1)	2 (2–2)	4 (4–6)
Questionnaire/prevalent conditions				
Age at survey (years)	53.1 (5.1)	53.4 (5.1)	53.2 (5.0)	51.5 (5.7)
Alcohol consumption (g/week)	31.0 (6.4–88.4)	31.8 (6.6–97.5)	29.0 (6.3–84.4)	39.0 (7.1–112.0)
Total energy intake, kJ/day	9638 (8146–11,289)	9317 (7831–10,975)	9661 (8200–11,347)	10,342 (8648–11,852)
Socioeconomic status	8.37 (4.24)	8.64 (4.30)	8.35 (4.19)	7.78 (4.34)
History of diabetes	79 (3.6)	28 (5.0)	49 (3.5)	2 (1.0)
Current smokers	670 (30.8)	203 (36.1)	429 (30.3)	38 (19.7)
Physical measurements				
BMI (kg/m^2)	26.9 (3.5)	26.9 (3.6)	26.7 (3.4)	27.8 (4.2)
SBP (mmHg)	134 (17)	135 (18)	133 (16)	135 (17)
DBP (mmHg)	89 (10)	89 (11)	88 (10)	90 (12)
Total physical activity (kcal/day)	1215 (655–2005)	1100 (559–1826)	1236 (681–2037)	1457 (680–2293)
Lipid markers				
Total cholesterol (mmol/l)	5.90 (1.08)	5.87 (1.10)	5.93 (1.08)	5.82 (1.02)
HDL-C (mmol/l)	1.30 (0.30)	1.27 (0.29)	1.30 (0.31)	1.32 (0.31)
Metabolic and inflammatory markers				
Fasting plasma glucose (mmol/l)	5.34 (1.23)	5.47 (1.55)	5.29 (1.10)	5.30 (1.07)
High-sensitivity CRP (mg/l)	1.25 (0.69–2.37)	1.53 (0.74–2.92)	1.20 (0.67–2.27)	1.21 (0.75–2.01)

BMI, body mass index; CHD, coronary heart disease; CRP, C-reactive protein; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; IQR, interquartile range; SD, standard deviation; SBP, systolic blood pressure.

Table 2
Association of frequency of sauna bathing and risk of all-cause cancer.

Frequency of sauna bathing (sessions/week)	Events/total	Model 1		Model 2	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Baseline frequency of sauna bathing					
≤1	155/563	ref		ref	
2–3	383/1417	0.87 (0.73–1.05)	0.158	0.92 (0.76–1.11)	0.373
≥4	50/193	0.87 (0.63–1.20)	0.388	0.92 (0.66–1.27)	0.614
Usual frequency of sauna bathing[a]					
≤1	155/563	ref		ref	
2–3	383/1417	0.82 (0.63–1.08)	0.158	0.88 (0.67–1.16)	0.373
≥4	50/193	0.82 (0.51–1.30)	0.388	0.89 (0.55–1.42)	0.614

CI, confidence interval; HR, hazard ratio; ref, reference.
Model 1: Adjusted for age.
Model 2: Model 1 plus body mass index, smoking status, history of diabetes, fasting glucose, triglycerides, total cholesterol, alcohol consumption, total energy intake, socioeconomic status, physical activity and high-sensitivity C-reactive protein.
[a] Indicates correction for within-person variability in values of frequency of sauna bathing, that is, the extent to which an individual's sauna bathing habits vary around long-term average values ("usual frequency of sauna bathing").

baseline assessments of sauna bathing frequency could under-estimate the risk by [(1/0.69)-1]*100 = 45% if there was a significant association between the frequency of sauna bathing and cancer risk. The HRs corresponded well after correction for within-person variability in sauna bathing frequency (Table 2). Given a sample of 2173 individuals including 588 incident cases of all-cause cancer, we had 100% power to detect a clinically important HR of 0.65 if there was a protective association between frequency of sauna bathing and cancer risk; alternatively, we had 99% power to detect a clinically important HR of 1.20 if sauna bathing increased the risk of cancer.

Similarly, there were no significant associations of frequency of sauna bathing with site-specific cancers (Tables 3–5). In analysis adjusted for age, the HR (95% (CI) of lung cancer was 0.20 (0.05–0.86) for men who had ≥ 4 sauna sessions per week compared with men who had ≤ 1 sauna session per week. The association however became non-significant on further adjustment for potential confounders 0.28 (95% CI: 0.07 to 1.21) (Table 5).

4. Discussion

Given conflicting evidence that heat therapy may be potentially associated with a reduced or increased risk of cancer, we sought to evaluate the prospective association between frequency of Finnish sauna bathing and the risk of cancer in a population-based cohort of middle-aged Caucasian men. Our results demonstrated no evidence of an association between Finnish sauna bathing and the future risk of all-cause cancer. The non-significant findings were consistent for prostate and gastrointestinal cancers, except for evidence of a protective effect on lung cancer in age-adjusted analysis which was, however, attenuated to null on multivariate adjustment. Our reproducibility studies of sauna bathing habits yielded a moderately high RDR, which indicates that sauna bathing habits may be relatively consistent within Finnish individuals over several years.

A number of research studies have demonstrated the effectiveness of hyperthermia (including infrared saunas) in dealing with cancer pain and also shrinking tumours (i.e., therapeutic hyperthermia) [5,7,10]. Given

Table 3
Association of frequency of sauna bathing and risk of prostate cancer.

Frequency of sauna bathing (sessions/week)	Events/total	Model 1		Model 2	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Baseline frequency of sauna bathing					
≤1	54/563	Ref		Ref	
2–3	146/1417	0.94 (0.69–1.29)	0.705	0.93 (0.68–1.27)	0.654
≥4	15/193	0.72 (0.40–1.27)	0.255	0.66 (0.37–1.19)	0.167
Usual frequency of sauna bathing[a]					
≤1	54/563	Ref		Ref	
2–3	146/1417	0.92 (0.58–1.44)	0.705	0.90 (0.57–1.42)	0.654
≥4	15/193	0.62 (0.27–1.42)	0.255	0.55 (0.24–1.28)	0.167

CI, confidence interval; HR, hazard ratio; Ref, reference.
Model 1: Adjusted for age.
Model 2: Model 1 plus body mass index, smoking status, history of diabetes, fasting glucose, triglycerides, total cholesterol, alcohol consumption, total energy intake, socioeconomic status, physical activity and high-sensitivity C-reactive protein.
[a] Indicates correction for within-person variability in values of frequency of sauna bathing, that is, the extent to which an individual's sauna bathing habits vary around long-term average values ("usual frequency of sauna bathing").

Table 4
Association of frequency of sauna bathing and risk of gastrointestinal cancer.

Frequency of sauna bathing (sessions/week)	Events/total	Model 1		Model 2	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Baseline frequency of sauna bathing					
≤1	31/563	Ref		Ref	
2–3	83/1417	0.94 (0.62–1.42)	0.775	1.02 (0.68–1.55)	0.911
≥4	16/193	1.40 (0.76–2.56)	0.278	1.57 (0.84–2.92)	0.157
Usual frequency of sauna bathing[a]					
≤1	31/563	Ref		Ref	
2–3	83/1417	0.92 (0.50–1.67)	0.775	1.04 (0.57–1.89)	0.911
≥4	16/193	1.63 (0.68–3.92)	0.278	1.92 (0.78–4.74)	0.157

CI, confidence interval; HR, hazard ratio; Ref, reference.
Model 1: Adjusted for age.
Model 2: Model 1 plus body mass index, smoking status, history of diabetes, fasting glucose, triglycerides, total cholesterol, alcohol consumption, total energy intake, socioeconomic status, physical activity and high-sensitivity C-reactive protein.
[a] Indicates correction for within-person variability in values of frequency of sauna bathing, that is, the extent to which an individual's sauna bathing habits vary around long-term average values ("usual frequency of sauna bathing").

Table 5
Association of frequency of sauna bathing and risk of lung cancer.

Frequency of sauna bathing (sessions/week)	Events/total	Model 1		Model 2	
		HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Baseline frequency of sauna bathing					
≤1	28/563	Ref		Ref	
2–3	62/1417	0.77 (0.49–1.20)	0.246	0.94 (0.60–1.49)	0.800
≥4	2/193	0.20 (0.05–0.86)	0.030	0.28 (0.07–1.21)	0.089
Usual frequency of sauna bathing[a]					
≤1	28/563	Ref		Ref	
2–3	62/1417	0.68 (0.36–1.30)	0.246	0.92 (0.47–1.78)	0.800
≥4	2/193	0.10 (0.01–0.80)	0.030	0.16 (0.02–1.32)	0.089

CI, confidence interval; HR, hazard ratio; Ref, reference.
Model 1: Adjusted for age.
Model 2: Model 1 plus body mass index, smoking status, history of diabetes, fasting glucose, triglycerides, total cholesterol, alcohol consumption, total energy intake, socioeconomic status, physical activity and high-sensitivity C-reactive protein.
[a] Indicates correction for within-person variability in values of frequency of sauna bathing, that is, the extent to which an individual's sauna bathing habits vary around long-term average values ("usual frequency of sauna bathing").

that evidence also suggest that heat therapy (particularly infrared saunas) could reduce the risk of cancer via plausible pathways [9,10], the current findings may therefore seem unexpected. The process of therapeutic hyperthermia involves heating the body tissues to a high temperature, which typically ranges from 41 to 45 °C [6,7]. Whereas infrared saunas operate at a lower temperature, gradually heat up the body and provide a form of whole-body hyperthermia, the heat from the Finnish sauna rapidly increases the skin temperature to about 40 °C, with the increases in temperature of other tissues being dependent on the heat exposure [19]. Hence, the null association observed between Finnish sauna bathing and cancer risk may reflect important pathophysiologic differences between the effects of heat exposure due to Finnish sauna baths and other passive heat therapies. The findings could also be attributed to factors such as age, sex or genetic background of the population. It is also possible that given different types of cancer do not have the same pathogenic process, exposure to Finnish saunas may impact site-specific cancers differentially. Though the study was adequately powered to evaluate associations for all-cause cancer, this was not so for site-specific cancers. Overall, our results do provide an important public health message indicating that regular Finnish sauna bathing does not increase cancer risk, given anecdotal reports suggesting that saunas (particularly infrared saunas) could increase the risk of cancer. If there is any association at all, it would be a beneficial one, given previous evidence and the direction of effect which suggest a protective effect especially for lung cancer. Finnish saunas have been demonstrated to have a beneficial effect on lung function and diseases such as common colds, chronic obstructive lung disease, asthma and pneumonia [11,20–24]. However, given this is the first assessment of the topic, other large-scale studies conducted particularly in women and otherage groups are warranted to confirm or refute these findings. The role of sauna in the prevention and treatment of chronic diseases is an area of active research and needs further investigation. The findings particularly for lung cancer need further exploration given the low event rate and hence poor power to detect an association if it truly existed.

The strengths of this work include the novelty with evaluation of all-cause and site-specific cancers, large sample size and prospective cohort design, long-term follow-up and zero-loss to follow-up with reliable FCR outcome data. An important strength of the present study is that repeat assessments of sauna bathing habits made within a random subset of individuals 11 years after baseline were available, which enabled correction for the extent of within-person variability in sauna bathing habits over the long period of follow-up. There were limitations and these included (i) the potential for misclassification of sauna assessment because it was based on self-reports; (ii) findings were based on middle-aged men and therefore not generalizable and (iii) study was not adequately powered for evaluating site-specific cancers.

In conclusion, frequent Finnish sauna bathing is not associated with the risk of all-cause, prostate, gastrointestinal or lung cancer in a middle-aged male Caucasian population. There is a potential for a protective effect on lung cancer, but this could have been limited by the low event rate. Further studies are required to confirm or refute these findings, particularly in women and other age groups.

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Conflict of interest statement

The authors declare they have no competing interests.

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Appendix. STROBE 2007 Statement—Checklist of items that should be included in reports of cohort studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	First page
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Second page
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction
Objectives	3	State specific objectives, including any prespecified hypotheses	Introduction
Methods			
Study design	4	Present key elements of study design early in the paper	Methods
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Methods
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Methods
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Methods
Bias	9	Describe any efforts to address potential sources of bias	Methods
Study size	10	Explain how the study size was arrived at	Methods

(*continued on next page*)

(*continued*)

Section/Topic	Item #	Recommendation	Reported on page #
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Methods
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Methods
		(*b*) Describe any methods used to examine subgroups and interactions	Methods
		(*c*) Explain how missing data were addressed	Not applicable
		(*d*) If applicable, explain how loss to follow-up was addressed	Not applicable
		(*e*) Describe any sensitivity analyses	Not applicable
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Results
		(b) Give reasons for non-participation at each stage	Results
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results; Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	Results
Outcome data	15*	Report numbers of outcome events or summary measures over time	Results
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Results; Tables 2-5
		(*b*) Report category boundaries when continuous variables were categorized	Results; Tables 2-5
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	Discussion
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Funding section

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