Is Sauna Bathing Protective of Sudden Cardiac Death? A Review of the Evidence

Running head: Sauna and SCD

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Abstract

Sudden cardiac death (SCD) is a global public health burden accounting for 15-20% of all deaths. Though established atherosclerotic risk factors explain a large proportion of the risk of SCD, these factors are often absent in a large proportion of SCD victims and the pathogenesis of SCD is still not fully established. It therefore appears that additional factors may be involved. Sauna bathing is a traditional Finnish activity that is mainly used for the purposes of relaxation and pleasure. Beyond its use for these purposes, sauna bathing has been linked with several health benefits. Emerging evidence suggests that sauna bathing is associated with reduced risk of adverse cardiovascular (CV) disease (CVD) and non-CVD outcomes as well as mortality. A number of reports have linked sauna bathing with reduced or increased risk of SCD, but the evidence is uncertain. This review summarizes available studies linking sauna bathing with SCD, the postulated mechanistic pathways underlying these associations, outlines areas of outstanding uncertainty, and the implications for prevention. We employed a comprehensive search for observational studies, randomized controlled trials (RCTs), and non-RCTs from MEDLINE and Embase since their inception until March 2019. Observational data suggest that regular sauna bathing is associated with a substantial risk reduction in SCD. Furthermore, the data suggest that a combination of regular physical activity and sauna baths confers substantial risk reduction for SCD compared with either modality alone. Few reports have linked sauna baths with SCDs, but these single case incidents have been attributed to the effects of dehydration, hypotension, and cardiac arrhythmias due to a combination of sauna exposure and alcohol consumption. Sauna bathing is generally safe for most healthy people and even among patients with stable CVD, if used sensibly and with caution. Plausible pathways underlying the protective effect of sauna bathing on SCD may be linked to the impact on CV function via reduced arterial stiffness, decreases in inflammation and oxidative stress, stabilization of the autonomic nervous system, beneficial changes in circulating lipid profiles and other CVD risk markers, and lowering of systemic blood pressure. Sauna is a potential novel tool to promote SCD prevention in addition to other known means, being an enjoyable way to take care of general health and well-being.

Keywords Finnish sauna bathing; sudden cardiac death

Abbreviations

BP=blood pressure; CHD=coronary heart disease; CRF = cardiorespiratory fitness; CRP = C-reactive protein; CV =cardiovascular; CVD=cardiovascular disease; HF= heart failure; KIHD = Kuopio Ischemic Heart Disease; MI= myocardial infarction ; PA=physical activity; RCT= randomized controlled trial; SCD = sudden cardiac death

Introduction

Sudden cardiac death (SCD) is a global public health burden, accounting for 15-20% of all deaths and approximately half of all deaths from cardiovascular (CV) disease (CVD). It is an ongoing challenge for affected families, physicians and healthcare systems.[1, 2] Coronary heart disease (CHD) is the most common associated pathology, underlying approximately 70% of all SCD events.[3] However, despite reported declines in the incidence of CHD over the past decades due to major advances in treatment and prevention strategies, [4, 5] SCD rates have declined to a lesser extent.[6] Through identification and greater knowledge of clinical risk factors for SCD, our understanding of SCD prevention is improving. However, the pathogenesis of every case of SCD is still not fully understood or established. Though established atherosclerotic risk factors explain a large proportion of the risk of SCD,[7] these factors are absent in a large proportion of SCD victims.[8] Thus, it appears that other factors may be involved in the pathogenesis of SCD. Abundant evidence in the arena of CV epidemiology supports the concept that the modulation of risk factors plays a pivotal role in SCD risk prediction and prevention. Therefore, identifying and understanding novel risk factors may offer new opportunities for SCD prevention in the population.

Sauna bathing, a passive heat therapy, is a traditional Finnish activity that is mainly used for the purposes of relaxation, wellness and pleasure.[9, 10] Beyond its use for these purposes, anecdotal reports have linked sauna bathing with a multitude of health benefits. Regular sauna bathing has been used as a method of "hardening," which means enhancing the body's resistance.[11] It has also been suggested that sauna bathing enhances elimination of toxins from the body as a result of increased sweating.[12] Over the last decade, a considerable amount of robust research reports have been published on the potential health benefits of sauna bathing as well as the putative mechanistic pathways underlying these effects. The evidence suggests that sauna bathing is associated with reduced risk of adverse CVD and non-CVD outcomes, as well as mortality.[13] Although a number of reports have linked sauna bathing with reduced or increased risk of SCD, the evidence is sparse and scanty. There is, therefore, a need to aggregate the data to enable appropriate interpretation. This review summarizes available evidence linking sauna bathing with SCD, the postulated mechanistic pathways underlying these

associations, outlines areas of outstanding uncertainty, and the implications for prevention. Although there exist different forms of passive heat therapy (eg., infrared-ray sauna, repeated hot water immersion, Waon therapy, Turkish bath, etc.), this review will only focus on evidence from the traditional Finnish saunas, since they are the most widely used and researched to date. We employed a comprehensive search for observational studies, randomized controlled trials (RCTs), and non-RCTs from MEDLINE and Embase since their inception until March 2019; with particular emphasis on Finnish sauna baths. Search terms included "sauna bath", "Finnish", "cardiovascular disease", "coronary heart disease", "sudden cardiac death, "mortality", "lipids", "hormones", "endothelial function", "inflammation", "oxidative stress", "arterial stiffness", "arterial compliance", and "intima media thickness". Studies were restricted to those in conducted in human adults and written in English.

Sudden Cardiac Death

The term SCD has generally been referred to as an unexpected death or cardiac arrest from a CVD cause.[1] It is commonly defined as an unexpected death from a CVD cause, which occurs typically shortly after the onset of symptoms, leaving only a little time for effective intervention.[1] Indeed, SCD is a devastating event which affects families, healthcare systems and global economies[1, 2] and is one of the leading causes of mortality and also responsible for approximately half of all deaths from CVD.[14] Though there is a dearth of information on SCD from global regions of low and-middle income countries, data abound in North American and European populations. The incidence of SCD in these regions is in the range of 50-100 per 100 000 in the general population.[1, 15] Also, SCD rates are reported to vary according to geographic area and climatic conditions.[16, 17]

Despite the relevance and societal burden of SCD and great improvements made in identifying risk factors for SCD, our understanding of the epidemiology and pathophysiology of SCD is still limited. The largest absolute number of SCDs occurs in the adult population and among previously asymptomatic individuals. Data from large-scale epidemiologic studies have identified several established and emerging risk factors for SCD (**Table 1**). Common non-modifiable risk factors for

SCD include age, sex and ethnicity. Compared to women, men have a three- to four-fold risk for SCD;[1] and it is also well established that African-American populations have higher SCD rates compared to Caucasians or Hispanics.[18] The incidence of SCD has also been reported to be lower among Asian populations.[19] Certainly, CHD is the most common structural pathology underlying majority of SCDs.[3] Indeed, CHD or atherosclerotic risk factors, such as obesity, hypertension, diabetes, dyslipidaemia, and cigarette smoking, explain a certain proportion of the risk of SCD.[7, 20, 21] Although these risk factors are established predictors of SCD at a population level, they are not specific enough to determine individual risk of SCD and have not been adequate to explain the pathogenesis of SCD. Lifestyle and environmental factors, such as dietary patterns (eg, Mediterranean-style diet, fish consumption), physical inactivity, cardiorespiratory fitness (CRF), emotional stress, alcohol use, air pollution, and seasonal variation, have also been linked to SCD.[22-27] Though available data support a decline in the incidence of SCD in recent years, contemporary data suggest a potential rise in rates.[28, 29] Therefore, there is a need to identify additional specific markers such as life-style risk factors which could be useful tools in SCD prevention.

Finnish Sauna Bathing

In Finland, sauna bathing is inexpensive and easily accessible to the majority of the population. As at the end of 2017, the estimated total number of saunas was over 2 million for the population of about 5.5 million.[30] Unlike other forms of passive heat therapies, the typical Finnish sauna has dry air and a high temperature with a good ventilation system. Sauna bathing is characterized by exposure to a high temperature dry environment for a brief period. The basic sauna is usually a wood-panelled room, with a rock-filled electric heater, and has wooden benches well above the floor for bathers to sit on (**Figure 1**). The benches are made of obeche, spruce, or aspen as they are less hot to sit on. The size of a sauna is at least 3 m^2 which ensures a correct balance between heat, humidity, and ventilation. The recommended temperature for a sauna bath is between 80°C to 100°C at the level of the bather's face, but it is lower (30°C) at the floor level to ensure efficient ventilation and to improve bather comfort.[31] Other forms of passive heat therapy run at temperatures between 45°C to 60°C . A good sauna should have efficient ventilation (i.e., the air should change 3 to 8 times per hour[32]). The air has a relative

humidity varying from 10 to 20%. The temperature and humidity can be temporarily increased by throwing water on the heated rocks. Usual sauna sessions consist of several short exposures in the sauna interspersed with periods of cooling-off (swim, shower, or a period at room temperature), followed by intake of fluids. The duration of stay in the sauna room usually ranges from 5-20 minutes depending on the temperature and comfort of the sauna bather; some individuals may have longer sauna bathing sessions.[33] The majority of Finns take 1 or more sauna baths a week, starting in childhood, but the average habitual frequency reported is 2-3 times per week.[34-36]

Sauna Bathing and Sudden Cardiac Death

Except for two studies published by our group, there is no other evidence on the long-term effects of regular sauna bathing on the risk of SCD in the general population. Laukkanen and colleagues employed the Kuopio Ischemic Heart Disease (KIHD) prospective study of 2315 middle-aged Finnish men whose self-reported sauna bathing habits were assessed at baseline and were followed over a period of 20.7 years. The study found increased frequency and duration of sauna bathing to be inversely associated with the risk of SCD and other CVD outcomes, as well as all-cause mortality.[35] Compared with men who took one sauna bathing session per week, the hazard ratio of SCD was 0.37 (95% confidence interval, 0.18 to 0.75) for men who took 4 to 7 sauna bathing sessions per week. Also, compared with men having sauna bathing sessions lasting less than 11 minutes, the hazard ratio for SCD was 0.48 (95% confidence interval, 0.31 to 0.75) for sessions lasting more than 19 minutes. These analyses took into account a comprehensive panel of potential confounders that could have influenced the associations, including age, body mass index, systolic blood pressure, serum low-density lipoprotein, cholesterol level, smoking, alcohol consumption, previous myocardial infarction (MI), type 2 diabetes mellitus, CRF, resting heart rate, physical activity (PA), and socioeconomic status. In another study that employed the KIHD cohort, Laukkanen and colleagues demonstrated that the combined effect of high CRF level and frequent sauna baths was associated with a substantially lowered risk of SCD compared with high CRF or frequent sauna bathing alone.[37] In this study of 2291 men, CRF was objectively measured (using respiratory gas exchange analyzers during cycle ergometer exercise testing) and self-reported sauna bathing habits were assessed at baseline. In this

analysis, CRF was categorized as low vs. high (using median cutoffs), and frequency of sauna bathing as low vs. high as well (defined as ≤2 and 3-7 sessions/week respectively). Cumulative hazard curves showed reduced risk of SCD among participants with high CRF and high frequency of sauna bathing compared with other groups (**Figure 2**). In analyses that adjusted for several confounders, compared to men with low CRF and low frequency of sauna bathing, the hazard ratios of SCD for the following groups: high CRF and high frequency of sauna bathing; high CRF and low frequency of sauna bathing; and low CRF and high frequency of sauna bathing were 0.31 (95% confidence interval, 0.16 to 0.63), 0.49 (95% confidence interval, 0.34 to 0.70), and 0.71 (95% confidence interval, 0.45 to 1.10), respectively.

Aside from these two studies, several other studies based on observational and interventional designs have reported a beneficial effect of sauna bathing on indices of CV function and intermediate phenotypes for SCD.[38-43]

Pathways Underlying the Protective Effect of Sauna Bathing on SCD

Sauna bathing creates a sense of wellbeing, relaxation, hedonia, or camaraderie, which reduces stress, a potential trigger of SCD.[3] We also propose plausible pathways underlying the protective effects of sauna bathing on SCD (**Table 2**). During a sauna session, the increased body temperature causes more efficient skin blood flow, leading to increased cardiac output, and blood flow to internal organs decreases.[31, 33]. The increased sweating is accompanied by a reduction in blood pressure, and the heart rate may increase from baseline up to 120-150 beats per minute. Though there is no active function of skeletal muscles during sauna baths, it has been reported that the response produced by an ordinary sauna bath corresponds to that produced by moderate or high intensity PA, such as walking.[44] Sauna bathing appears to work comparably to PA by systemic blood pressure reduction;[41] reduction in oxidative stress[45, 46] and inflammation;[42, 47] improvement in endothelial function;[48-50] positive alteration in levels of circulating lipids;[51, 52] improvement in glucose metabolism;[53] improved arterial stiffness, arterial compliance, and intima media thickness;[36, 45, 54-56] and improvement in the cardiorespiratory system[57] as well as CV function[31, 33, 58]. Some early evidence indicates that sauna bathing improves cardiac autonomic nervous system balance, leading to an increase in vagal tone and

a decrease in sympathetic tone, with positive modulations in heart rate variability during the recovery from sauna.[38] Serious arrhythmias leading to SCD may be triggered due to cardiac autonomic nervous system unbalance, and sauna bathing could be a potential stabilizing factor with its positive modulating effects.[38] All these pathways contribute to beneficial CV health and may underline the protective effect of sauna bathing on SCD. Furthermore, sauna sessions stimulate the production of hormones such as plasma renin, cortisol, growth hormone, and norepinephrine.[59-61] The levels of norepinephrine induced by sauna exposure have been reported to be similar to levels triggered by maximal PA.[62] Though regular PA has an established role in reducing the risk of chronic diseases and CVD outcomes,[63-67] there have been reports that vigorous exercise might trigger SCDs.[67, 68] However, most studies support the notion that PA lowers the risk of SCD.[69] Given the emerging evidence of a protective effect of sauna exposure on SCDs, it is plausible that the combination of both activities might confer additional protection. Indeed, we have recently shown that a combination of high CRF levels and frequent sauna bathing confers stronger long-term protection on SCD compared with high CRF or frequent sauna bathing alone.[37] The benefits of combining exercise with sauna use should not be discounted, as it may be a gateway to encouraging a people healthier lifestyle. Further evidence is needed to demonstrate the mechanistic pathways linking sauna bathing and SCD.

Sudden Deaths as Adverse Events of Sauna Bathing

Sauna bathing has a good safety profile and is generally tolerated by most people who are in good health.[31, 70] Evidence also suggests that sauna bathing is well tolerated among individuals with stable heart disease, such as a prior MI and those with stable angina pectoris or compensated heart failure (HF).[31, 71] There have been single-case reports of SCD, stroke, or transient ischemic attacks as a result of sauna exposure, but the consumption of alcohol has been estimated to be a key contributing factor in those cases.[72, 73] The interaction of sauna and alcohol intoxication increases the risk of dehydration, hypotension, hemoconcentration, cardiac arrhythmias, and accidents.[71, 74] Sauna exposure could also trigger MI or sudden death in patients with unstable conditions such as unstable CHD, orthostatic hypotension, cardiac arrhythmias, or severe valvular disease such as aortic stenosis.[33] Furthermore, of the few sudden deaths that have been reported during or after sauna bathing in countries that routinely

use saunas, majority of the victims had existing CHD.[75] Patients with unstable angina pectoris, recent MI, severe aortic stenosis, uncontrolled hypertension, or ischemic or decompensated HF are advised to avoid sauna because of the increased risk of strokes or SCD.[31, 71, 76]

Though the practice of short stays in the sauna room interrupted with rapid cooling-off in cold water or shower is widely practiced and has generally been regarded as safe for healthy individuals, it may be linked with cardiac arrhythmias in patients with a history of CVD (such as a prior acute MI or severely reduced left ventricular function) [77, 78] and hence not recommended as a safe practice in such populations.[79] However, in HF patients, hot sauna exposure and cold water immersion have been shown to be haemodynamically well tolerated.[38] There is no doubt that the practice of alternating heat exposure and cold water immersion puts a substantial strain on the cardiovascular system, and hence, individuals with an unstable CVD should avoid heat-cold immersion.[70] A number of case fatalities have been reported to have occurred when individuals dived head first into cold water immediately after a sauna bath[80], and this is attributed to constriction of the coronary arteries which decreases coronary blood flow and oxygen delivery to the heart.[44]

Conclusions

Sauna bathing appears to be associated with a substantial risk reduction in SCD, but this is based on limited observational evidence. Other large-scale observational cohort studies are needed to replicate these observations and well-designed RCTs are also needed to confirm this. Furthermore, the data suggest that a combination of regular PA and sauna baths confers substantial risk reduction for SCD compared with each modality alone. Taking the overall evidence together, sauna bathing appears to be linked to a remarkable array of CV benefits. The benefits of sauna bathing far outweigh the risks. Indeed, further work is needed to clarify the pathophysiological mechanisms that underlie the associations between sauna bathing and its CV benefits, including prevention of SCD. However, in the absence of these, sauna bathing remains a safe and pleasurable recreational activity that can be used to enhance health and wellness. For people with underlying CVD, caution is required, the individual's tolerance should be checked, and appropriate contact should be made with a physician.

Combining sauna bathing with regular PA is a more attractive option to use for CV benefits than substituting PA with sauna bathing. In addition, since there is a low prevalence of meeting the PA guidelines among all age, sex and race/ethnic groups,[67, 81] sauna bathing may be a useful adjunct to PA in promoting a healthy lifestyle.

References

1. Wong CX, Brown A, Lau DH, et al. Epidemiology of Sudden Cardiac Death: Global and Regional Perspectives. *Heart Lung Circ.* 2019;28:6-14.

2. Gillum RF. Geographic variation in sudden coronary death. *Am Heart J.* 1990;119:380-389.

3. Hayashi M, Shimizu W, Albert CM. The spectrum of epidemiology underlying sudden cardiac death. *Circ Res.* 2015;116:1887-1906.

4. Dudas K, Lappas G, Stewart S, Rosengren A. Trends in out-of-hospital deaths due to coronary heart disease in Sweden (1991 to 2006). *Circulation.* 2011;123:46-52.

5. Gerber Y, Jacobsen SJ, Frye RL, Weston SA, Killian JM, Roger VL. Secular trends in deaths from cardiovascular diseases: a 25-year community study. *Circulation.* 2006;113:2285-2292.

6. Deo R, Albert CM. Epidemiology and genetics of sudden cardiac death. *Circulation.* 2012;125:620-637.

7. Grundy SM, D'Agostino Sr RB, Mosca L, et al. Cardiovascular risk assessment based on US cohort studies: findings from a National Heart, Lung, and Blood institute workshop. *Circulation.* 2001;104:491-496.

8. Spooner PM, Zipes DP. Sudden death predictors: an inflammatory association. *Circulation.* 2002;105:2574-2576.

9. Perasalo J. Traditional use of the sauna for hygiene and health in Finland. *Ann Clin Res.* 1988;20:220-223.

10. Valtakari P. The sauna and bathing in different countries. *Ann Clin Res.* 1988;20:230-235.

11. Heckmann JG, Kukkonen-Harjula K. Sauna and risk of stroke: Does frequent sauna bathing prevent stroke? *Neurology.* 2018;90:993-994.

12. Laukkanen JA, Laukkanen T, Kunutsor S. In reply—Sauna Bathing and Healthy Sweating. *Mayo Clinic Proceedings.* 2019;94:727-728.

13. Laukkanen JA, Laukkanen T, Kunutsor SK. Cardiovascular and Other Health Benefits of Sauna Bathing: A Review of the Evidence. *Mayo Clin Proc.* 2018;93:1111-1121.

14. Myerburg RJ, Castellanos A. *Cardiac Arrest and sudden cardiac death (in Braunwald's heart disease: a textbook of cardiovascular medicine)*. Philadelphia: Saunders; 2007.

15. Mahmoud KD, de Smet BJ, Zijlstra F, Rihal CS, Holmes DR, Jr. Sudden cardiac death: epidemiology, circadian variation, and triggers. *Current problems in cardiology.* 2011;36:56-80.

16. Chugh SS, Jui J, Gunson K, et al. Current burden of sudden cardiac death: multiple source surveillance versus retrospective death certificate-based review in a large U.S. community. *J Am Coll Cardiol.* 2004;44:1268-1275.

17. Hua W, Zhang LF, Wu YF, et al. Incidence of sudden cardiac death in China: analysis of 4 regional populations. *J Am Coll Cardiol.* 2009;54:1110-1118.

18. Shah KS, Shah AS, Bhopal R. Systematic review and meta-analysis of out-of-hospital cardiac arrest and race or ethnicity: black US populations fare worse. *Eur J Prev Cardiol.* 2014;21:619-638.

19. Zheng ZJ, Croft JB, Giles WH, Mensah GA. Sudden cardiac death in the United States, 1989 to 1998. *Circulation.* 2001;104:2158-2163.

20. Albert CM, Chae CU, Grodstein F, et al. Prospective study of sudden cardiac death among women in the United States. *Circulation.* 2003;107:2096-2101.

21. Adabag AS, Luepker RV, Roger VL, Gersh BJ. Sudden cardiac death: epidemiology and risk factors. *Nat Rev Cardiol.* 2010;7:216-225.

22. Albert CM, Hennekens CH, O'Donnell CJ, et al. Fish consumption and risk of sudden cardiac death. *JAMA.* 1998;279:23-28.

23. Chiuve SE, Fung TT, Rexrode KM, et al. Adherence to a low-risk, healthy lifestyle and risk of sudden cardiac death among women. *JAMA.* 2011;306:62-69.

24. Chiuve SE, Rimm EB, Mukamal KJ, et al. Light-to-moderate alcohol consumption and risk of sudden cardiac death in women. *Heart rhythm : the official journal of the Heart Rhythm Society.* 2010;7:1374-1380.

25. Dennekamp M, Akram M, Abramson MJ, et al. Outdoor air pollution as a trigger for out-of-hospital cardiac arrests. *Epidemiology.* 2010;21:494-500.

26. Jimenez-Pavon D, Artero EG, Lee DC, et al. Cardiorespiratory Fitness and Risk of Sudden Cardiac Death in Men and Women in the United States: A Prospective Evaluation From the Aerobics Center Longitudinal Study. *Mayo Clin Proc.* 2016;91:849-857.

27. Laukkanen JA, Makikallio TH, Rauramaa R, Kiviniemi V, Ronkainen K, Kurl S. Cardiorespiratory fitness is related to the risk of sudden cardiac death: a population-based follow-up study. *J Am Coll Cardiol.* 2010;56:1476-1483.

28. Bray JE, Di Palma S, Jacobs I, Straney L, Finn J. Trends in the incidence of presumed cardiac out-of-hospital cardiac arrest in Perth, Western Australia, 1997-2010. *Resuscitation.* 2014;85:757-761.

29. Feng JL, Nedkoff L, Knuiman M, et al. Temporal Trends in Sudden Cardiac Death From 1997 to 2010: A Data Linkage Study. *Heart Lung Circ.* 2017;26:808-816.

30. Statistics Finland. Accessed from https://www.stat.fi/tup/suoluk/suoluk_asuminen_en.html. Date accessed: 15 April 2019.

31. Hannuksela ML, Ellahham S. Benefits and risks of sauna bathing. *Am J Med.* 2001;110:118-126.

32. Helamaa E, Aikas E. The secret of good 'loyly'. *Ann Clin Res.* 1988;20:224-229.

33. Kukkonen-Harjula K, Kauppinen K. Health effects and risks of sauna bathing. *Int J Circumpolar Health.* 2006;65:195-205.

34. Kunutsor SK, Khan H, Laukkanen T, Laukkanen JA. Joint associations of sauna bathing and cardiorespiratory fitness on cardiovascular and all-cause mortality risk: a long-term prospective cohort study. *Ann Med.* 2018;50:139-146.

35. Laukkanen T, Khan H, Zaccardi F, Laukkanen JA. Association between sauna bathing and fatal cardiovascular and all-cause mortality events. *JAMA internal medicine.* 2015;175:542-548.

36. Lee E, Laukkanen T, Kunutsor SK, et al. Sauna exposure leads to improved arterial compliance: Findings from a non-randomised experimental study. *Eur J Prev Cardiol.* 2017:doi: 10.1177/2047487317737629.

37. Laukkanen J, Laukkanen T, Khan H, Babar M, Kunutsor SK. Combined effect of sauna bathing and cardiorespiratory fitness on the risk of sudden cardiac deaths in Caucasian men: a long-term prospective cohort study. *Prog Cardiovasc Dis.* 2018 Mar 15. pii: S0033-0620(18)30058-6.

38. Radtke T, Poerschke D, Wilhelm M, et al. Acute effects of Finnish sauna and cold-water immersion on haemodynamic variables and autonomic nervous system activity in patients with heart failure. *Eur J Prev Cardiol.* 2016;23:593-601.

39. Laukkanen T, Kunutsor SK, Zaccardi F, et al. Acute effects of sauna bathing on cardiovascular function. *J Hum Hypertens.* 2018;32:129-138.

40. Lee E, Laukkanen T, Kunutsor SK, et al. Sauna exposure leads to improved arterial compliance: Findings from a non-randomised experimental study. *Eur J Prev Cardiol.* 2018;25:130-138.

41. Zaccardi F, Laukkanen T, Willeit P, Kunutsor SK, Kauhanen J, Laukkanen JA. Sauna Bathing and Incident Hypertension: A Prospective Cohort Study. *Am J Hypertens.* 2017;30:1120-1125.

42. Kunutsor SK, Laukkanen T, Laukkanen J. Longitudinal associations of sauna bathing with inflammation and oxidative stress: The KIHD prospective cohort study. *Annals of medicine.* 2018.

43. Kunutsor SK, Hakkinen A, Zaccardi F, et al. Short-term effects of Finnish sauna bathing on blood-based markers of cardiovascular function in non-naive sauna users. *Heart Vessels.* 2018;33:1515-1524.

44. Vuori I. Sauna bather's circulation. *Ann Clin Res.* 1988;20:249-256.

45. Sutkowy P, Woźniak A, Boraczyński T, Mila-Kierzenkowska C, Boraczyński M. The effect of a single Finnish sauna bath after aerobic exercise on the oxidative status in healthy men. *Scand J Clin Lab Invest.* 2014;74:89-94.

46. Masuda A, Miyata M, Kihara T, Minagoe S, Tei C. Repeated sauna therapy reduces urinary 8-epi-prostaglandin F(2alpha). *Jpn Heart J.* 2004;45:297-303.

47. Laukkanen JA, Laukkanen T. Sauna bathing and systemic inflammation. *Eur J Epidemiol.* 2017 Dec 5. doi: 10.1007/s10654-017-0335-y. [Epub ahead of print].

48. Ohori T, Nozawa T, Ihori H, et al. Effect of repeated sauna treatment on exercise tolerance and endothelial function in patients with chronic heart failure. *Am J Cardiol.* 2012;109:100-104.

49. Imamura M, Biro S, Kihara T, et al. Repeated thermal therapy improves impaired vascular endothelial function in patients with coronary risk factors. *J Am Coll Cardiol.* 2001;38:1083-1088.

50. Kihara T, Biro S, Imamura M, et al. Repeated sauna treatment improves vascular endothelial and cardiac function in patients with chronic heart failure. *J Am Coll Cardiol.* 2002;39:754-759.

51. Gryka D, Pilch W, Szarek M, Szygula Z, Tota L. The effect of sauna bathing on lipid profile in young, physically active, male subjects. *Int J Occup Med Environ Health.* 2014;27:608-618.

52. Pilch W, Szygula Z, Klimek AT, et al. Changes in the lipid profile of blood serum in women taking sauna baths of various duration. *Int J Occup Med Environ Health.* 2010;23:167-174.

53. Brenke R. Das Potenzial der Sauna im Rahmen der Prävention - eine Übersicht neuerer Erkenntnisse. *Complementary Medicine Research.* 2015;22:320-325.

54. Miyata M, Kihara T, Kubozono T, et al. Beneficial effects of Waon therapy on patients with chronic heart failure: results of a prospective multicenter study. *J Cardiol.* 2008;52:79-85.

55. Brunt VE, Howard MJ, Francisco MA, Ely BR, Minson CT. Passive heat therapy improves endothelial function, arterial stiffness and blood pressure in sedentary humans. *J Physiol.* 2016;594:5329-5342.

56. Ganio MS, Brothers RM, Shibata S, Hastings JL, Crandall CG. Effect of passive heat stress on arterial stiffness. *Exp Physiol.* 2011;96:919-926.

57. Scoon GS, Hopkins WG, Mayhew S, Cotter JD. Effect of post-exercise sauna bathing on the endurance performance of competitive male runners. *J Sci Med Sport.* 2007;10:259-262.

58. Crandall CG, González-Alonso J. Cardiovascular function in the heat-stressed human. *Acta Physiol (Oxf).* 2010;199:407-423.

59. Kauppinen K, Vuori I. Man in the sauna. *Ann Clin Res.* 1986;18:173-185.

60. Tei C, Horikiri Y, Park JC, et al. Acute hemodynamic improvement by thermal vasodilation in congestive heart failure. *Circulation.* 1995;91:2582-2590.

61. Von E. Quantitation of Stress by Catecholamine Analysis. *Clin Pharmacol Ther.* 1964;5:398-404.

62. Laustiola K, Seppala E, Vuorinen P, Salo M, Uusitalo A, Vapaatalo H. The effect of pindolol on exercise-induced increase in plasma vasoactive prostanoids and catecholamines in healthy men. *Prostaglandins Leukot Med.* 1985;20:111-120.

63. Cheng W, Zhang Z, Cheng W, Yang C, Diao L, Liu W. Associations of leisure-time physical activity with cardiovascular mortality: A systematic review and meta-analysis of 44 prospective cohort studies. *Eur J Prev Cardiol.* 2018;25:1864-1872.

64. Lear SA, Hu W, Rangarajan S, et al. The effect of physical activity on mortality and cardiovascular disease in 130 000 people from 17 high-income, middle-income, and low-income countries: the PURE study. *Lancet.* 2017;390:2643-2654.

65. Kyu HH, Bachman VF, Alexander LT, et al. Physical activity and risk of breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events: systematic review and dose-response meta-analysis for the Global Burden of Disease Study 2013. *BMJ.* 2016;354:i3857.

66. Lee DC, Brellenthin AG, Thompson PD, Sui X, Lee IM, Lavie CJ. Running as a Key Lifestyle Medicine for Longevity. *Prog Cardiovasc Dis.* 2017;60:45-55.

67. Ozemek C, Laddu DR, Lavie CJ, et al. An Update on the Role of Cardiorespiratory Fitness, Structured Exercise and Lifestyle Physical Activity in Preventing Cardiovascular Disease and Health Risk. *Prog Cardiovasc Dis.* 2018;61:484-490.

68. Reddy PR, Reinier K, Singh T, et al. Physical activity as a trigger of sudden cardiac arrest: the Oregon Sudden Unexpected Death Study. *Int J Cardiol.* 2009;131:345-349.

69. Whang W, Manson JE, Hu FB, et al. Physical exertion, exercise, and sudden cardiac death in women. *JAMA.* 2006;295:1399-1403.

70. Schmid JP. Some like it hot: Cardiovascular health benefits of Finnish sauna. *Eur J Prev Cardiol.* 2018;25:127-129.

71. Luurila OJ. The sauna and the heart. *J Intern Med.* 1992;231:319-320.

72. Ylikahri R, Heikkonen E, Soukas A. The sauna and alcohol. *Ann Clin Res.* 1988;20:287-291.

73. Heckmann JG, Rauch C, Seidler S, Dutsch M, Kasper B. Sauna stroke syndrome. *J Stroke Cerebrovasc Dis.* 2005;14:138-139.

74. Roine R, Luurila OJ, Suokas A, et al. Alcohol and sauna bathing: effects on cardiac rhythm, blood pressure, and serum electrolyte and cortisol concentrations. *J Intern Med.* 1992;231:333-338.

75. Suhonen O. Sudden coronary death in middle age and characteristics of its victims in Finland. A prospective population study. *Acta Med Scand.* 1983;214:207-214.

76. Eisalo A, Luurila OJ. The Finnish sauna and cardiovascular diseases. *Ann Clin Res.* 1988;20:267-270.

77. Keatinge WR, Evans M. The respiratory and cardiovascular response to immersion in cold and warm water. *Q J Exp Physiol Cogn Med Sci.* 1961;46:83-94.

78. Schmid JP, Morger C, Noveanu M, Binder RK, Anderegg M, Saner H. Haemodynamic and arrhythmic effects of moderately cold (22 degrees C) water immersion and swimming in patients with stable coronary artery disease and heart failure. *Eur J Heart Fail.* 2009;11:903-909.

79. Keast ML, Adamo KB. The Finnish sauna bath and its use in patients with cardiovascular disease. *J Cardiopulm Rehabil.* 2000;20:225-230.

80. Vuori I. Healthy and unhealthy sauna bathing. *Ann Clin Res.* 1988;20:217-219.

81. Katzmarzyk PT, Lee IM, Martin CK, Blair SN. Epidemiology of Physical Activity and Exercise Training in the United States. *Prog Cardiovasc Dis.* 2017;60:3-10.

Table 1. Established and Emerging Risk Factors for Sudden Cardiac Death

Demographics
Older age
Male gender
Race or ethnicity (African-American)
Atherosclerotic Risk Factors
Dyslipidaemia
Diabetes
Hypertension
Cigarette smoking
Obesity
Lifestyle, socioeconomic, and psychosocial factors
Excessive alcohol consumption
Physical inactivity (low cardiorespiratory fitness)
Diet (n-3 polyunsaturated fatty acids, Mediterranean diet)
Recreational drug use
Depression
Anxiety
Psychosis
Social isolation
High degree of life stress
Low socioeconomic status
Low educational status
Ischemic and non-ischemic structural heart disease
Coronary heart disease
Previous myocardial infarction
Heart failure
Left ventricular dysfunction
Dilated cardiomyopathy
Hypertrophic cardiomyopathy
Arrhythmogenic right ventricular dysplasia
Valvular heart disease
Congenital heart defects
Infiltrative diseases (sarcoidosis, amyloidosis)
Comorbidities
Atrial fibrillation
Ventricular tachycardia of fibrillation
Chronic kidney disease
Obstructive sleep apnoea
Primary or inherited arrhythmic disorders
Long and short QT syndrome
Brugada syndrome
Wolff–Parkinson–White syndrome
Arrhythmogenic right ventricular cardiomyopathy
Catecholaminergic polymorphic ventricular tachycardia
Electrocardiographic parameters
Heart rate
Prolonged QRS duration
Pathologic Q waves or dynamic ST segment changes
QTc interval
QRS-T angle
QRS transition zone
T-peak-to-T-end interval
Increased R wave voltage
Genetics
Family history of sudden cardiac death
Family history of long QT syndrome, Wolff-Parkinson-White syndrome
Specific mutations/polymorphisms
Environmental factors
Air pollution
Diurnal/seasonal variation

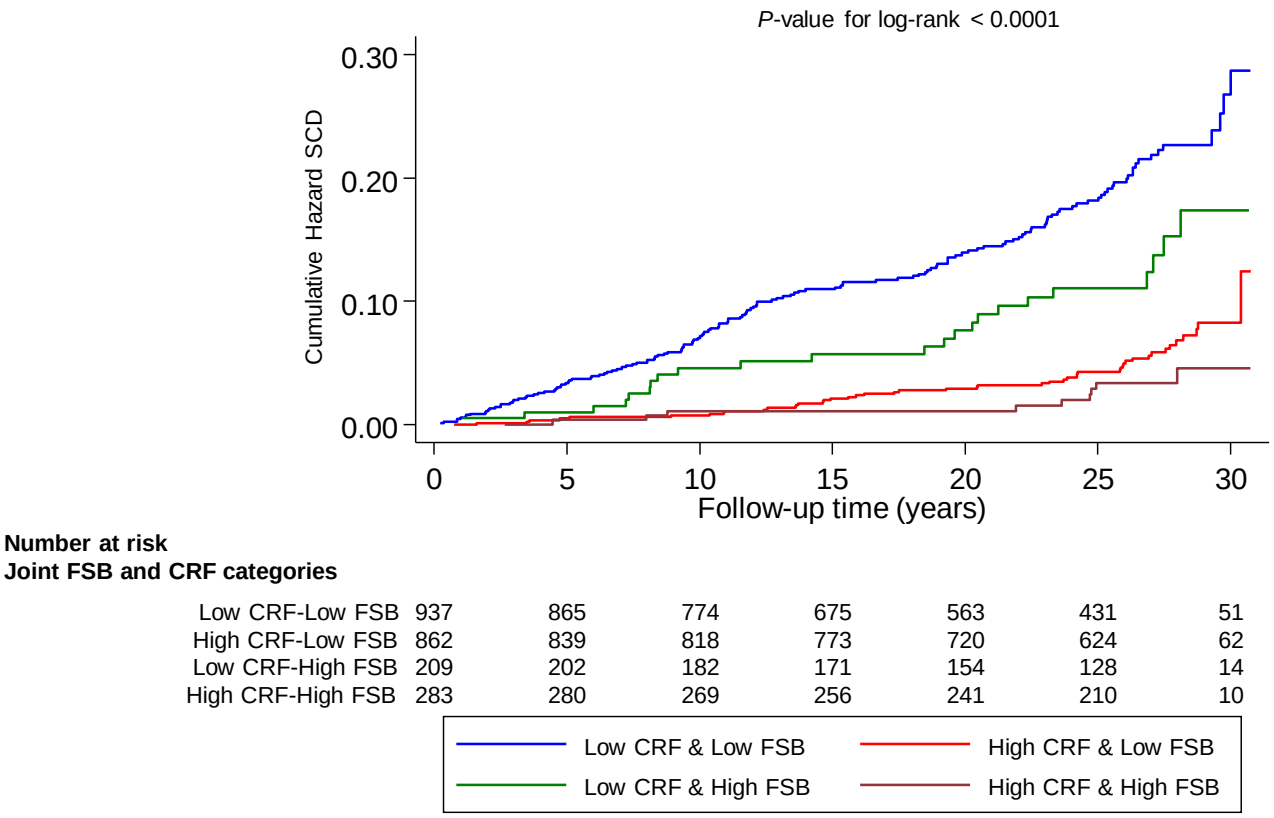
Table 2. Postulated Mechanistic Pathways Underlying Protective Effects of Sauna Bathing on SCD

Decrease in systemic blood pressure
Improved endothelial function
Improved arterial stiffness, arterial compliance, and intima media thickness
Stabilization of the autonomic nervous system
Reduced inflammation
Improved glucose metabolism, sensitizing the tissue for the insulin-dependent glucose uptake
Improved immune responses
Improvement in cardiorespiratory function
Stimulate hormones such as plasma renin, cortisol, growth hormone, and norepinephrine
Reduction in total cholesterol, LDL-cholesterol, and triglycerides, with increase in HDL-cholesterol
Antioxidative properties (improved defence against free radicals)

HDL, high density lipoprotein; LDL, low density lipoprotein

Figure 1. A Typical Finnish Sauna

Figure 2. Cumulative Kaplan-Meier Curves for Sudden Cardiac Death During Follow-up According to CRF and Sauna Bathing Frequency Groups



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CRF, cardiorespiratory fitness; FSB, frequency of sauna bathing