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# The Impact of Sauna Bathing on Cardiovascular Homeostasis: From Molecular Mechanism to Clinical Benefits

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## ABSTRACT

**Background.** Cardiovascular diseases (CVD) remain the leading cause of death worldwide, thereby demanding novel and scalable preventive approaches. In recent years, sauna bathing and infrared Waon therapy have emerged as potential pleiotropic intervention replicating the effects of aerobic training.

**Aim**. This review aims to summarize the evidence currently available from large prospective cohort studies and from randomized controlled trials on the influence of short-term thermal stress on hemodynamic parameters, endothelial function, arterial stiffness and long-term cardiovascular prognosis.

**Material and methods.** A systematic literature search was performed using data from major prospective cohort studies in Finnish and Swedish populations as well as interventional trials on thermal therapy. The review summarizes the results on molecular mechanisms (HSPs, Nrf2), hemodynamics and clinical benefits such as mortality, stroke and hypertension by meta-analysis.

**Results.** Observational studies strongly indicate that dose-dependent sudden cardiac death (63% reduction), stroke (61%), and hypertension are low in the frequent sauna users (4–7 times per week). These effects are mediated through upregulation of heat shock proteins (HSPs), modulation of the autonomic nervous system, and suppression of systemic inflammation. However, the results of studies testing these advanced exercise training strategies in patients with established CAD are conflicting regarding potential improvement in vascular function compared to healthy subjects, potentially resulting from a "healthy user" bias or structural limitations when disease is severe.

**Conclusions.** Acute heat treatment may serve as a hormetic stressor that triggers beneficial pleiotropic adaptations. While the epidemiological evidence on risk reduction is strong for modification of these potentially reversible factors, the failure to demonstrate vascular benefit in short-term trials of advanced CAD patients demands additional investigation into the optimal approach regarding patient population, timing and duration of therapy.

**Keywords:** sauna bathing, cardiovascular risk, heat stress response, hormesis, endothelial function, cold stress

## 1. Introduction

Sauna bathing is a habit with a long history in Nordic culture and has been used for thousands of years for hygiene, pleasure and social purposes. In Finland, the classic sauna consists of short-time high temperature (80°C to 100°C) and low humidity exposures (10-20%), alternated with periods of cooling. In contrast, far-infrared (FIR) saunas and Waon therapy, the standard in Japan, expose the body to lower (approximately 60°C) temperatures that heat up the body via thermal radiation rather than air from a sauna room (Hannuksela & Ellahham, 2001; Tei et al., 2016).

Although the procedures differ somewhat in methodology, both treatments induce mild hyperthermia (i.e., an increase of 1-2°C core temperature) including a thermal load that challenges thermoregulatory responses and closely mimics those observed during moderate-to-heavy intensity exercise. For these reasons, sauna bathing is being studied not only as a recreational activity but also as an "exercise mimetic" and lifestyle intervention to promote the health span and reduce cardiovascular burden (Patrick & Johnson, 2021). The concept of hormesis,  adaptive response to mild stress, is key to understating how occasional heat can offer long-term health benefits. The aim of this review is to provide comprehensive exploration of the physiology, clinical data, and ongoing controversies related to thermal therapy.

## 2. Materials and methods

This review synthesizes data from original sources, which includes landmark studies as (Walker et al., 1997). Major observational data are from the Kuopio  Ischemic Heart Disease Risk Factor Study (KIHD), a population-based prospective cohort of over 2000 middle-aged Finnish men followed for over 20 years, and the MONICA study (Multinational Monitoring of Trends and Determinants in Cardiovascular Disease) conducted in Northern Sweden. Interventional data have been analysed from randomized controlled trials (RCTs) assessing vascular endothelial function (FMD), arterial stiffness (PWV) and hemodynamic responses in healthy adults and patients with stable CAD. The present review critically examines the physiological basis of thermal therapy, comparing acute and chronic effects.

## 3. Research results

### 3.1. Physiological and molecular mechanisms of heat acclimation

The cardiovascular effects of sauna bathing are mediated by an interplay of hemodynamic changes and molecular adaptations. Repeated exposure results in heat acclimatization, which is defined by a reduction in resting core temperature, an increase in plasma volume and optimized sweating efficiency.

#### 3.1.1. Hemodynamic Response and Flow Redistribution

The increase in skin temperature to occurs quickly after a sudden hot exposure, whereas the increase in core temperature is more gradual. To promote heat loss through sweating (0.6–1.0 kg/h), 50–70% of cardiac output is redistributed from the splanchnic circulation to the skin circulation (Brunt & Minson,  2021). This extensive vasodilation causes a dramatic decrease in Total Peripheral Resistance (TPR). To compensate the blood pressure perfusion, there is heart rate (HR) elevation till 100–150 beat per minute and the cardiac output (CO) is increased by 60–70%, while stroke volume (SV) remains relatively stationary or even a little bit greater. This hemodynamic profile is analogous to the physiological load of moderate aerobic exercise, e.g. brisk walking. Moreover, this "unloading" of the heart by decreasing afterload is technically a good thing for patients in heart failure (improvement in cardiac function without requiring active muscular contraction) (Laukkanen et al., 2018).

#### 3.1.2. Molecular Chaperones and Oxidative Stress Mechanisms

Having been demonstrated that, at a cellular scale, heat stress triggers the strong expression of Heat Shock Proteins (HSPs), in particular HSP70 family. As molecular chaperones, HSPs help prevent protein aggregation and refold denatured proteins as well maintain proteostasis that is lost during aging and cardiovascular disorders. High intracellular HSP expression has been linked to protection against ischemia-reperfusion injury and suppression of proinflammatory pathways (Iguchi et al., 2012).

In addition, heat stress plays a role in the activation of the Nrf2 (nuclear factor erythroid 2-related factor 2) pathway. Nrf2 is a key regulator of the antioxidant response, which controls the transcriptional activation of enzymes including heme oxygenase-1 (HO-1). HO-1 catabolizes heme to carbon monoxide and bilirubin with strong anti-inflammatory and cytoprotective activities. This pathway decreases expression of vascular cell adhesion molecule-1, and intercellular adhesion molecule-1 on the vascular endothelium; hence resulting in direct anti-atherogenic effects and preservation of the endothelial integrity. (Patrick & Johnson, 2021; Sastriques-Dunlop et al., 2025).

#### 3.1.3. Endothelial Function and Autonomic Modulation

Thermal therapy improves endothelial function through NO availability. So, one of the factors that might be mediating the effect is increasing shear stress in relation to nitric oxide synthase (eNOS) expression during sauna high-flow state (Miyata & Tei, 2010). NO play a fundamental role in vascular tone and prevention of atherosclerosis.

The effect of sauna on the autonomic nervous system (ANS) is biphasic and adaptive. At the immediate onset of heating, sympathetic activity becomes prevailing by increasing heart rate and redistributing blood flow. The acute flushing effect of sauna is balanced over time by a post-sauna reduction in heart rate (HR) and arterial blood pressure, but also by long-term increases in vagal tone and dynamic circulatory control; reflected quantitatively as increased

HR-variability (HRV), a powerful surrogate for autonomic health and immunity against fatal arrhythmias. A systematic review of Ferreira et al. (2023) stressed that although the acute effects of whole-body heating induce an increase in sympathetic modulation, local heating (i.e., foot baths) and post-sauna bathing recovery are followed by increased cardiac vagal modulation.

### 3.2. Impact on Cardiovascular Risk Factors

#### 3.2.1. Hypertension and Arterial Stiffness

Hypertension is a major reversible risk factor for CVD. In the Kuopio Ischemic Heart Disease (KIHD) prospective study, men who used a sauna 4–7 times per week had a 46% reduced probability of developing hypertension compared to those using it only once per week (HR = 0.54; 95% CI: 0.32–0.91) (Zaccardi et al., 2017). This protective effect remained after controlling for cardiorespiratory fitness, indicating an independent advantage of thermotherapy. Experimentally, support for this comes from evidence that a single 30-minute sauna exposure rapidly decreases carotid-femoral pulse wave velocity (PWV) – the gold-standard measure of arterial stiffness – from 9.8 m/s to 8.6 m/s. SBP also decreased from 137 to 130 mmHg, an effect sustained during the 30 – minute recovery phase (Lee et al., 2017).

However, interaction between sauna and blood pressure is complex. In a recent re-analysis of the KIHD population during an average 19 years of follow-up, Laukkanen et al. (2023) report that frequent sauna bathing appears to reduce the risk of cardiovascular death in relation to "high-normal" (130-139) SBP. However, it has a minimal effect or is ineffective among individuals with already established severe hypertension (≥140 mmHg). This suggests a threshold effect, where blood vessel response to heat is confined to no more than the extreme stiffening of pathology.

#### 3.2.2. Systemic Inflammation

Low-grade systemic inflammation is a central modifiable aspect of the development of atherosclerosis. A study with 2084 men participating in the KIHD provided a strong inverse dose-response relation between frequency of sauna bathing and serum concentration of C-reactive protein (CRP). Resting CRP concentrations were lower in those who bathed 4–7 times/week than the reference group of once-weekly bathing (1.65 mg/L vs 2.41 mg/L) (Laukkanen & Laukkanen, 2018). Such an anti-inflammatory effect may also be related to the increase of anti-inflammatory cytokines such as IL-10 and the decrease in oxidative stress through the Nrf2 pathway.

### 3.3. Hard Clinical Outcomes

#### 3.3.1. Sudden Cardiac Death (SCD) and CVD Mortality

The strongest evidence for sauna comes from long-term epidemiological data. In the prospective KIHD cohort, followed for a median 20.7 years, men using the sauna 4–7 times per week had a reduction of SCD (a HR for SCD of 0.37 and for fatal CVD of 0.50 compared with those having a single use per week). A 40% decrease in the risk of all-cause mortality has been observed as well (Laukkanen et al., 2015).

The length of the session was also important with, >19 minutes amounting to an even greater level of protection (HR 0.48 for SCD) compared to sessions of <11 minutes. Furthermore, high cardiorespiratory fitness (CRF) combined with frequent sauna bathing conferred a particularly strong protection against mortality risk than either factor alone. Together this indicates that the sauna bathing serves a supporting role to physical activity but acts through partially separate or additive processes.

#### 3.3.2. Stroke Prevention

Sauna bathing provides a significant neurovascular protection. Kunutsor et al. (2018) stated that regular sauna bathing (4–7 times/week) was related to reduced risk of incident stroke by 61% (HR, 0.39) in a follow-up period of 15 years. The association was strongest for ischemic stroke, probably due to the combined effect of decreased blood pressure, better endothelial function and reduced arterial stiffness.

#### 3.3.3. Peripheral Arterial Disease (PAD) and Heart Failure

Waon therapy is expected to provide better clinical outcomes in PAD patients. The thermal therapy is effective to improve the ankle-brachial index ABI, extending pain-free walking distance significantly, and decreasing total pain scores (Tei et al., 2007). These clinical improvements are believed to be related to improved microcirculation, decreased oxidative stress and increased angiogenesis through the stimulation of CD34+ endothelial progenitor cells.

In the same way, in patients with chronic heart failure (CHF), repeated dry sauna (Waon therapy) has been reported to improve New York Heart Association functional class and increase left ventricular ejection fraction (LVEF), as well as to decrease B-type natriuretic peptide (BNP). Moreover, it reduced the prevalence of ventricular arrhythmias, suggesting its safety as an adjunct therapy for heart failure (Tei et al., 2016).

### 3.4. Other benefits aside from cardiovascular health.

Sauna bathing has also been associated with lowered risk of neurodegenerative diseases. High sauna bathing frequency was linked to a 66% decreased risk of dementia, and a 65% lower risk of Alzheimer's disease (Laukkanen et al., 2017 in Patrick & Johnson, 2021). Potential mechanisms could be enhanced cerebral blood flow and BDNF (Brain-Derived Neurotrophic Factor) upregulation due to heat stress. Furthermore, regular sauna use is linked to decreased risk of respiratory diseases (pneumonia and COPD), potentially due to improved lung function and particularly decreased pulmonary congestion (Laukkanen et al., 2018).

## Discussion

### 4.1. The efficacy paradox: Between observational and interventional data.

In contrast, the strength of the observational data from the KIHD cohort is also remarkable, indicating causation although not conclusively. An RCT by Debray et al. (2023) challenged the concept of a sauna bathing as a vascular cure-all and attempted to disprove the putative universal benefits for the circulation of sauna. In this study, 41 participants with stable CAD were randomized to an 8-week Finnish sauna intervention (4 sessions/week) or a control group.

The intervention successfully indicated signs of heat acclimation: reduced resting core temperature and augmented sweat rate. However, in contrast to what would have been anticipated from observational studies, the sauna exposure did not have any beneficial impact on brachial FMD (Flow-Mediated Dilation), PWV or resting blood pressure compared with controls.

This contrast between strong epidemiological evidence and the null result of a well-executed RCT leads to few important considerations:

- Structural Stiffness: Patients with advanced atherosclerosis (stable CAD) may possess structural vascular changes, such as calcification and fibrosis that are resistant to short-term heat-based therapy. First, the cardiovascular benefits achievable in healthy or at-risk populations may not be attainable after definite structural deterioration.
- Healthy User Bias: Although the observations may be, partly confounded by differences between sauna and non-sauna users (sauna users being younger, more physically active and of higher socioeconomic status). The MONICA study conducted in Sweden also found

that sauna bathers had healthier lifestyle habits, including greater physical activity and lower smoking rates (Engström et al., 2024).

- Duration and Timing: A lifelong exposure that is usual in the Finnish cohorts, frequently beginning at an earlier age than as adults may be required to prevent vascular aging and achieve structural benefits. An 8-week period of intervention may not be enough to undo years of cumulative vascular damage.

### 4.2. Psychosocial and Quality of Life

In addition to measurable vascular benefits, subjective well-being is meaningfully affected by sauna bathing. In the MONICA study in Northern Sweden (2024), sauna bathers also reported much better levels of happiness, energy and sleep satisfaction, than non-sauna bathers, and fewer days with pain. Such a psychological benefit (energetic, mental health) was also noticed with less-frequent use (1–4 times /month), in contrast with the high frequency (4–7 times /week) necessary for reduction in hard cardiovascular mortality. This suggests that the threshold for achieving improvements in quality of life is lower than that required for vascular remodelling. The social dimension of sauna bathing additionally promotes stress reduction and psychological health.

### 4.3. Impact of moderate cold stress

In sauna bathing, it is common practice to apply an acute cold stressor (e.g., cold shower or ice-cold water immersion) following heat exposure. This causes a primary vasoconstrictive effect followed by rebound vasodilation in limbs and distal tissues, restoring warm blood flow and generating shear stress to improve vascular function and peripheral circulation. Heat-cold cycling is a strong mediator of this response. Cold exposure also activates brown adipose tissue (BAT) mostly in neck and supraclavicular regions burning energy through thermogenesis Repeated exposure increases its oxidative capacity and activity, modulating lipid metabolism (Heinonen & Laukkanen, 2018).

### 4.4. Safety Profile

Because of the low risk of dehydration (which can be mitigated by drinking adequate fluids), sauna bathing is generally safe among patients with stable CVD, such as those with previous myocardial infarction or compensated heart failure. Rare and mild adverse events (e.g., transient dizziness) occur in studies. However, specific contraindications exist:

- Unstable angina pectoris.
- Recent myocardial infarction (<6 weeks).
- Severe aortic stenosis.
- Decompensated heart failure.

Alcohol consumption during sauna bathing is an extremely dangerous practice. It is a major life-threatening risk factor for myocardial ischemia (especially in patients suffering from unstable angina pectoris), hypotension, arrhythmias and sudden death related to poor thermoregulation and excessive vasodilatation. (Hussain & Cohen, 2018).

**5. Conclusions**

Regular heat treatment is a hormetic stressor that leads to pleiotropic adaptations that benefit the cardiovascular system, including improved vascular endothelial function, decreased arterial stiffness and systemic inflammation. Substantial epidemiological evidence demonstrates a strong inverse association between frequent sauna bathing (4–7 sessions per week) and the risk of incident hypertension, stroke, sudden cardiac death, and all-cause mortality.

However, randomized controlled trials in patients with extensive coronary artery disease have shown no vascular benefit, highlights potential limitations of sauna bathing. This shown that the therapeutic window for reversal of vascular dysfunction may be limited in advanced disease states, or extended durations of intervention periods are necessary. Future research should be determining the therapeutic "dose" (frequency, duration and intensity of heat) for individual clinical populations as well as differentiating between preventative and therapeutic benefit. Passive heat therapy continues to show potential as an adjunctive treatment, especially for those populations that are unable to exercise, provided it is not combined with alcohol consumption.

**Disclosure**

Authors do not report any disclosures.

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