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The blood pressure and heart rate during sauna bath correspond to cardiac responses during submaximal dynamic exercise

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ABSTRACT

Objectives: In the present study, the reaction of blood pressure and heart rate are examined during and after a single acute sauna application.
Design: In 19 healthy adult volunteers (7 women, aged 46.4 ± 10.2 years, BMI 24.4 ± 2 kg /m^2), blood pressure (BP) and heart rate (HR) were measured during a 25-minute sauna session (93°C, 13 % humidity) and during a subsequent 30-minute rest period. The parameters obtained were compared with the BP and HR responses during submaximal dynamic exercise testing.
Results: The heat exposure resulted in a significant ($p < 0.01$) and progressive increase in systolic and diastolic BP. After the sauna bath, BP decreased and showed significantly ($p < 0.001$) lower values compared to baseline. HR also increased continuously during heat application ($p < 0.001$), resulting in a significant increase ($p < 0.001$) in systolic BP x HR as a measure of myocardial oxygen consumption. After the end of the sauna session, both the BP and the HR decreased steadily ($p < 0.001$).When comparing BP and HR during the sauna session with the reaction during a dynamic exercise test, sauna bathing was equivalent to an exercise load of about 60-100 watts.
Conclusions: Contrary to popular belief, acute sauna use does not lead to a reduction, but to an increase in BP and HR with a consequent increase in myocardial oxygen consumption. The cardiac load during the sauna use corresponds to a moderate physical load of 60-100 watts.

1. Introduction

Regular sauna bathing not only promotes subjective well-being but also causes various positive cardiovascular and hormonal changes and is therefore also recommended for maintaining and promoting good health. In addition to reducing the risk of respiratory diseases, [1] regular sauna sessions can have a beneficial effect on neuropathic and rheumatoid complaints, [2] improve cardiovascular function, [3,4] and reduce the risk for arterial hypertension. [5] Even in patients with chronic heart failure, repeated sauna treatment improves both cardiac function and exercise tolerance.[6] Laukkanen and colleagues [7] found an inverse relationship between a higher frequency of sauna visits and the risk of sudden cardiac death, fatal coronary heart diseases, fatal cardiovascular diseases and overall mortality.

The mechanisms underlying this beneficial effect are not entirely yet fully understood. Several Various mechanisms have been discussed for the beneficial effects of heat application, including an improvement in endothelial function,[6,8] a reduction in oxidative stress,[9] modulations of the autonomic nervous system,[10] a change in the level of circulating natriuretic peptides [11] as well as an improvement in arterial compliance.[4]

Although the long-term effects of sauna bathing have been extensively studied, the acute effects during a single sauna session are less clear and are primarily limited to measurements in the recovery phase after the sauna session.[4]

Acute sauna bathing leads to a reduction of both systolic and diastolic pressure as well as pulse wave velocity in the recovery period after heat exposure.[3,4] Based on these results and assuming, that the external heat on the body causes a vasodilatory effect,[12] a continuous decrease in blood pressure (BP) during an acute sauna bath is suspected. It has also been pointed out in previous reports that sauna bathing can lead to fainting in unstable patients.

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Table 1
Subjects' Characteristics.

Male/Female (n)	12/7
Age (yrs)	46 ± 10
Height (cm)	178.2 ± 9.1
Body Weight (kg)	75.8 ± 11.2
Body-Mass-Index ($kg \cdot m^{-2}$)	23.8 ± 3.0

mean ± SD.

Therefore, the aim of the present study was to investigate the acute effect on the BP and heart rate (HR) not only after the sauna but especially during the acute sauna stay. To assess the cardiac load during the sauna stay, the subjects additionally performed a submaximal standardized exercise test on the bicycle ergometer, which also determined BP and HR. Thus, the hemodynamic responses and cardiac stress during heat stress in the sauna can be approximated by comparing them to responses of BP and HR during standardized exercise.

2. Material and methods

2.1. Study design and population

Participants were recruited from a local sports and health care center. Nineteen healthy volunteers (36.8% women, aged 46.4 ± 10.2 years, BMI 24.4 ± 2 kg/m^2) were randomly selected and included in the experimental non-randomized study (Table 1).

All participants were recreationally active, non-smokers aged 18–60 years. Subjects underwent full medical screening on a work-free Saturday to rule out exclusion criteria (secondary hypertension, severe cardiovascular or cerebrovascular complications, metabolic or pulmonary disease). None had coronary heart disease or heart failure, and their serum creatinine concentration did not exceed 1.1 mg/dl. Sauna bathing habits (monthly sauna sessions and duration of sauna exposure) were assessed by means of a questionnaire.

In addition to the screening visit, the study consisted of a single sauna session and a submaximal exercise test on a cycle ergometer, performed in a random order on two separate sessions on the same day of the week. In order to avoid possible circadian influences on the measured parameters, they were performed at the same time of day.

Each participant was informed about the purpose and course of the study and gave verbal and written consent. The Institutional Review Board approved the study design. The study was conducted in accordance with the Guidelines for Good Clinical Practice and was in line with the Helsinki Declaration on the use of human subjects for research.

2.2. Sauna exposure and exercise testing

Participants were exposed to a single 25-minute sauna session sitting in a traditional finish sauna.[6] Temperature in the sauna was 93 ± 3 °C with a humidity of 13–20%. The temperature and humidity were monitored throughout the entire session in the sauna in sitting height with a special sauna thermometer / hygrometer (Finnsa GmbH, Germany).

In order to keep the humidity in the sauna stable, no sauna infusions were carried out. Participants could leave the sauna at any time if they felt uncomfortable. Fluid intake was not allowed during sauna stay. After the 25-minute session in the sauna, participants were instructed to leave the sauna immediately and rest in a designated room with controlled room temperature (25 ± 1 °C), in a sitting position for 30 min. Ice or cold water showers as well as fluid intake were not allowed during rest. BP and HR were determined at rest prior to the start of the sauna, during the sauna session and during the subsequent 30-minute rest period.

On a separate day, BP and HR were measured during submaximal exercise tests. Participants were subjected to a commonly used standardized ergometric testing in a half-sitting position on a stationary bicycle ergometer (Schwarzer EL900B) under controlled conditions, using techniques given in the Proposal for International Standardization of Ergometry[13] and according to the proposals of the WHO/International Society of Hypertension.[14,15] The exercise load started at 50 W, with an increase of 10 W every minute to a maximum of 100 W. During bicycle ergometry, BP was measured at the end of each exercise minute and in the 1 st, 3rd and 5th recovery minute after the exercise test. Heart rate (HR) was monitored continuously during the test. The product of HR x systolic BP, as a correlate of myocardial oxygen (O_2) consumption,[16] was calculated at 100 W.

2.3. Experimental measures

The subjects were instructed to abstain from caffeine and alcoholic beverages for 12 h, to abstain from food for 4 h, and to stop exercising and sauna bathing 24 h before the examinations.

BP was measured indirectly over the brachial artery with a validated conventional mercury sphygmomanometer (Boso, Germany) according to the Riva-Rocci-Korotkoff cuff method in a sitting position. One experienced physician has performed all BP measurements.

After a 5-minute seated rest in a quiet environment with a constant room temperature (25 ± 1 °C), two baseline measurements were taken before sauna bathing and stress testing. The obtained measurements were averaged for analysis. All measurements (resting, sauna, and exercise tests) were performed with the right arm extended and positioned so that the heart and the customized pressure cuff were at the same level. HR was determined using RS800CX heart rate monitor (Polar, Finland).

2.4. Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics 22.0 (SPSS, Chicago, IL, USA). All data were statistically checked for normality. The Levene test was used to check the homogeneity of variance. To test comparisons between baseline and different time points during and after the sauna bathing and exercise test, repeated measurement ANOVAs were performed. Bonferroni post-hoc analyses were performed to examine pairwise mean differences. Data are expressed as mean ± 1 standard deviation (SD). The level of statistical significance was considered $p < 0.05$.

3. Results

All participants were regular sauna attendants and went to the sauna either two (5.3%), three (36.8%) or four (57.9%) times per month. The average duration of sauna exposure was 19.4 ± 6.2 min as three participants left the sauna room earlier due to discomfort.

The systolic BP was already after 5 min Sauna stay significantly higher ($p < 0.01$) than before the sauna stay and rose continuously. Diastolic BP also increased after 5 min but then remained elevated during the stay in the sauna (Fig. 1).

Five minutes after leaving the sauna session, both systolic and diastolic BP were significantly lower ($p < 0.01$) than pre-sauna levels. Furthermore, systolic BP decreased steadily throughout the 30-minute rest period. Systolic and diastolic BP were lower ($p < 0.01$) after 30 min of recovery when compared to pre-sauna values (Fig. 1). When comparing the BP reaction during the sauna visit with the BP increase during ergometry, the BP response during sauna bathing corresponded to the BP at a dynamic load of about 60 W (Fig. 2),

HR also increased steadily during heat application ($p < 0.001$). After the sauna, the HR decreased steadily ($p < 0.001$), but did not return to baseline within the 30 min of rest (Fig. 3). The increase in HR during the sauna visit corresponded to the HR increase during ergometry at a load of 100 W (Fig. 4).

The product of systolic BP and HR, a measure of myocardial oxygen

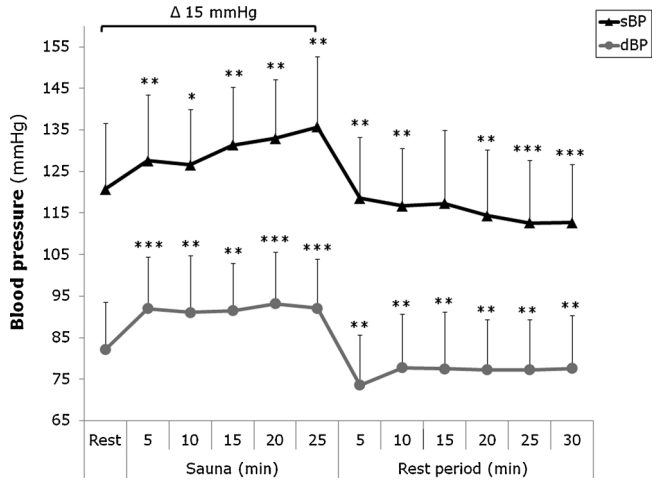

Fig. 1. Systolic (sBP) and diastolic blood pressure (dBP) at rest before, during and after an acute sauna session (mean ± SD) * $p < 0.05$; ** $p < 0.01$; *** $p < 0001$ different from rest before sauna session.

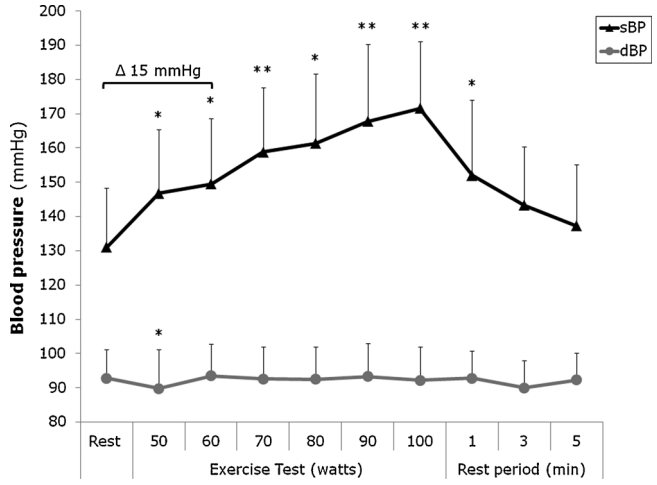

Fig. 2. Systolic (sBP) and diastolic blood pressure (dBP) at rest before, during and after exercise testing (mean ± SD) * $p < 0.05$; ** $p < 0.01$ different from rest before exercise.

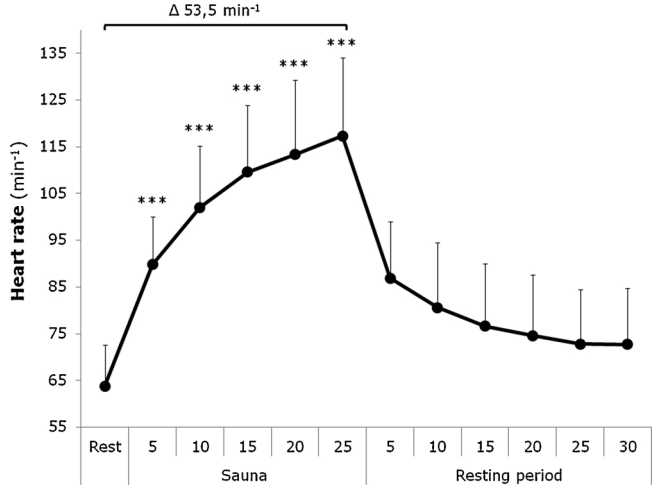

Fig. 3. Heart rate at rest before, during and after an acute sauna session (mean ± SD) *** $p < 0.001$ different from rest before sauna session.

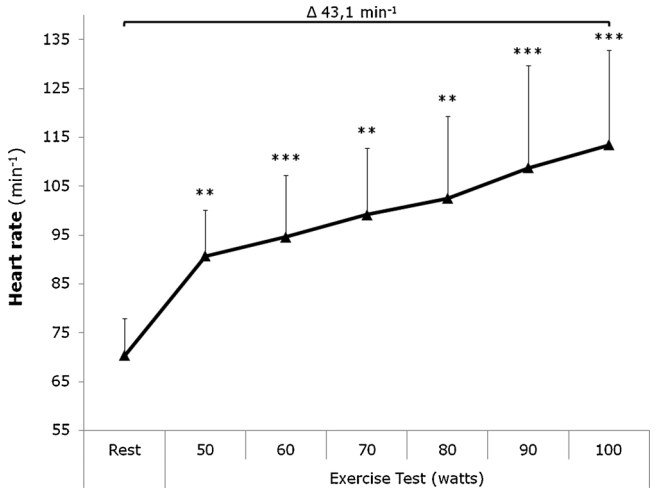

Fig. 4. Heart rate at rest before and during exercise testing (mean ± SD) ** $p < 0.01$; *** $p < 0.001$ different from rest before exercise.

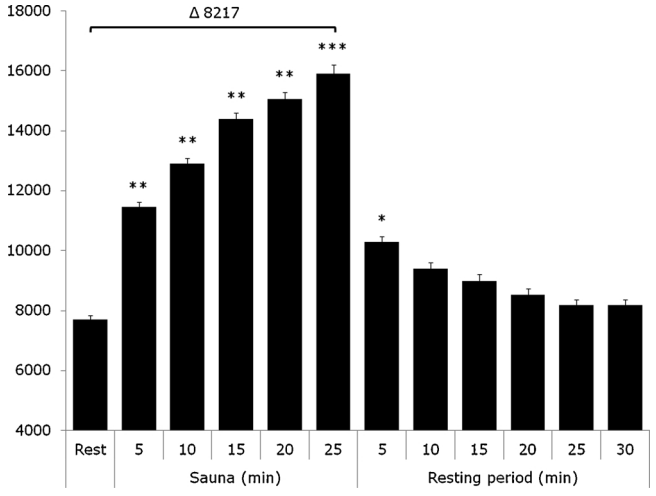

Fig. 5. Product of heart rate and systolic blood pressure before, during and after an acute sauna session (mean ± SD) * $p < 0.05$; ** $p < 001$; *** $p < 0.001$ different from rest before exercise.

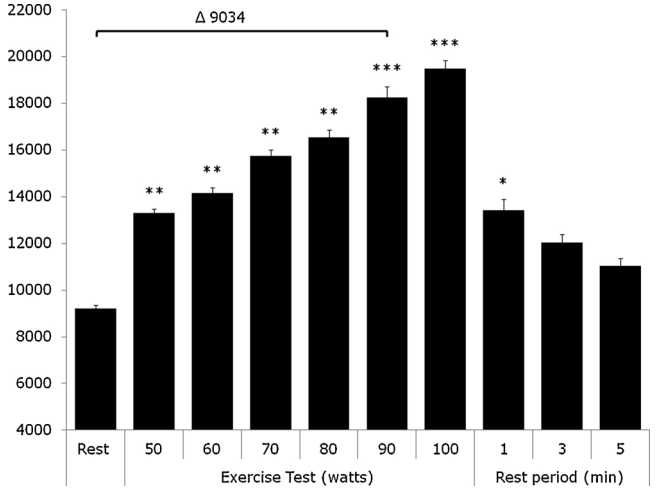

Fig. 6. Product of heart rate and systolic blood pressure before, during and after exercise testing (mean ± SD) * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ different from rest before exercise.

consumption, showed an increase of 107% ($p < 0.001$) during the sauna bath (Fig. 5). The increase in the product of systolic BP x HR during the sauna corresponds to the increase in the product during ergometry at a load of 90 W (Fig. 6).

4. Discussion

As demonstrated in the present study, there was an increase in BP and HR during the stay in the sauna. This also results in an increase of more than 100% in the product of systolic BP and HR, which allows an indirect assessment of myocardial O_2-consumption.[17,18] This means that there is a significant increase in heart stress during the sauna stay.

This is in contrast to the statements of some older studies where, due to the lower BP after sauna use, it was wrongly concluded that there was already a drop in BP during the sauna stay, which was explained by a heat-induced vasodilation. However, the BP was not measured at all during the sauna stay.[19,20] By contrast, the observed increase in heart rate is consistent with previous studies [21,22] and would be due to various mechanisms, such as an increase in plasma catecholamines, activation of the sympathetic nervous system, and the renin-angiotensin-aldosterone system, as well as a response of the hypothalamus-pituitary-adrenal hormonal axis.[23,24]

If the measurements during the acute sauna session are compared with parameters determined during the ergometry test, the cardiac load in the sauna corresponds to a moderate physical exercise load of 60–100 watts. Accordingly, sauna bathing does not seem to be contraindicated in well-adjusted and healthy subjects. In patients with coronary heart disease (CAD), however, Gianetti and colleges [22] found an association between sauna bathing and asymptomatic myocardial ischemia. The authors therefore recommend that patients suffering from CAD who are at risk of recurrent exercise induced myocardial ischemia should be made aware of the potential risk of ischemia during sauna exposure or should refrain from visiting the sauna.

In the resting phase after the sauna session, the expected reduction of BP, which has already been described in other studies, could be demonstrated even after 30 min.[3,4] The underlying mechanism of this drop in BP after sauna bathing could be due to fluid loss during the sauna stay, which could reduce the stroke volume. The average fluid loss of the participants in the present study was almost one liter. On the other hand it has been reported that the circulation of the skin during the stay in the sauna increases from about 5%–10% to 50%–70% of the cardiac output.[25] This increase in circulation persists after leaving the sauna and slowly declines during the cooling phase. A decrease in total peripheral resistance has to be discussed as well.[19]

The effects of acute and repeated sauna loading are similar to what we know from moderate aerobic exercise where we observed an increase in BP and HR during acute training and a decrease in both parameters at rest after exercise.[26] Thereafter it may be argued that heat stress represents a cardiac burden similar to physical exercise and thus may be a potential preventive strategy for cardiovascular risk factors and diseases.

Repeated sauna application with repeated stimulation of different activation systems [19,10] improves vascular endothelial function in healthy individuals and also in patients with cardiovascular risk factors.[8] Regular visits to the sauna (5 times a week for 3 weeks) reduced norepinephrine plasma levels by about 25% and improved the flow-mediated dilation (FMD) of endothelial function by almost 60%.[6] In the long-term, sauna bathing lowers both systolic and diastolic BP, comparable to antihypertensive monotherapy [27] as we have demonstrated with regular aerobic exercise training.[26] A recent article adds new insights that passive heat therapy such as sauna bathing, with an average frequency of twice a week, could improve cardiovascular health and reduce the risk of vascular events.[28] It can therefore be speculated that the repeated cardiovascular stress during sauna application with a subsequent drop in BP could be an incentive for long-term BP regulation.

4.1. Study limitations

There are some limitations in the current study. First, the sample size of 19 participants is relatively small. Second, besides BP and HR no other cardiovascular parameters were evaluated. It therefore remains unproven whether the acute drop in BP after sauna bathing is due to fluid loss, reduced stroke volume, or reduced total peripheral resistance. Furthermore, the results are limited to the typical Finnish sauna protocol with relatively high temperatures and fairly long bath duration. It is possible that a lower temperature, a shorter duration and different humidity may have different effects. Similarly, a cohort that is more adapted to sauna application may show different responses to heat application. Additionally, the patient's cardio-respiratory status might play a role in the sauna bathing response, as a study by Laukkanen et al [4] suggests.

4.2. Conclusion

In summary, the results of the present study can provide new insights that underlie the emerging relationships between acute sauna bath and cardiovascular stress.

Contrary to previous reports that a BP drop occurs during a sauna stay causing fainting in unstable patients, the data presented shows a continuous increase in BP during the sauna session. Furthermore, the results indicate that the acute heat exposure in the sauna is a burden comparable to moderate physical exercise. In addition, the sustained decrease in BP after heat exposure suggests that the sauna bath will have a beneficial effect on the cardiovascular system. Further epidemiological and experimental studies could help elucidate the effects of regular sauna bathing on hemodynamic function.

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Conflict of interest

The authors declare that they have no conflict of interest.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Statement

Both authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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