# Comparison of physiological reactions and physiological strain in healthy men under heat stress in dry and steam heat saunas

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# COMPARISON OF PHYSIOLOGICAL REACTIONS AND PHYSIOLOGICAL STRAIN IN HEALTHY MEN UNDER HEAT STRESS IN DRY AND STEAM HEAT SAUNAS

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**ABSTRACT:** The aim of the paper was to follow up major physiological reactions, provoked by heat stress during dry and wet sauna baths. A physical strain index and subjective estimation of heat comfort of subjects who had not taken sauna baths before was also evaluated. Ten healthy males aged 25-28 underwent a dry sauna bath and then after a one-month break they underwent a steam sauna bath. Each time, they entered the sauna chamber 3 times for 15 minutes with five-minute breaks. During breaks they cooled their bodies with a cold shower and then rested in a sitting position. Before and after the baths, body mass and blood pressure were measured. Rectal temperature and heart rate were monitored during the baths. The physiological strain index (PSI) and cumulative heat strain index (CHSI) were calculated. Subjects assessed heat comfort by Bedford's scale. Greater body mass losses were observed after the dry sauna bath compared to the wet sauna (-0.72 vs. -0.36 kg respectively). However, larger increases in rectal temperature and heart rate were observed during the wet sauna bath (38.8% and 21.2% respectively). Both types of sauna baths caused elevation of systolic blood pressure, but changes were greater after the dry one. Diastolic pressure was reduced similarly. Subjective feelings of heat comfort as well as PSI (4.83 ± 0.29 vs. 5.7 ± 0.28) and CHSI (76.3 ± 18.4 vs. 144.6 ± 21.7) were greater during the wet sauna bath. It can be concluded that due to high humidity and reduction of thermoregulation mechanisms, the wet sauna is more stressful for the organism than the dry sauna, where the temperature is higher with low humidity. Both observed indexes (PSI and CHSI) could be appropriate for objective assessment of heat strain during passive heating of the organism.

**KEY WORDS:** finnish sauna, wet steam bath, heat stress indexes

## INTRODUCTION

Recently athletes are using various new methods for recovery and improving their performance, such as massage under hypoxic conditions [5], electrical muscle stimulation [23] or cryostimulation [3] – just to mention a few of them. Dry Finnish sauna and wet steam bath are still common methods of biological regeneration which are used by athletes [28]. Both types of sauna have been known for centuries. A dry sauna bath is a cycle of two to three entrances into the hot temperature chamber (80-100°C) with low humidity (5-25%) interrupted by whole body cooling. The other type of sauna is the wet steam bath, which is also called Russian Banya, where the hot air (40-70°C) is fully saturated by the steam.

Sauna bath is used as an element of heat therapy. The advantages of sauna are: greater resistance to winter infections, reduction of toxins with perspiration and, most importantly, physical and physiological relaxation [1,7,11]. Both types of heat baths influence the following systems: cardiovascular, hormonal, nervous and excretory systems [2,9,12,16,19,20,26]. Thanks to cooperation of these systems and other organs, sauna bath has a positive effect on the whole organism [7,8,16]. The changes which occur in the human organism due to exposure to high temperatures are varied. The elevation of body temperature is observed, but skin temperature rises faster than temperature of internal organs. To eliminate excess body heat, different mechanisms are engaged: skin blood flow rises, perspiration is enhanced, and lung ventilation increases. Because of heat exposure, autonomic nervous system activation occurs. It is manifested by increased heart rate and elevated concentration of catecholamines in plasma [7,8,19-21].

High air humidity in a wet steam bath causes difficulties in evaporation of sweat from the surface of the skin. This may slow down the removal of heat from the body. Different conditions in wet and dry sauna cause different responses of the organism. There are various methods for assessing the magnitude of heat strain during physical effort, such as the Bedford thermal scale, physiological strain index (PSI) and cumulative heat strain index (CHSI). The mentioned indexes have not been used previously for the assessment of heat strain during passive heating. Therefore the aim of this work was to follow the changes in physiological variables and to evaluate and compare the influence of both types of sauna on a healthy person's mood (by the Bedford thermal scale) as well as the magnitude of heat strain by the physiological strain index (PSI) and cumulative heat strain index (CHSI).

## MATERIALS AND METHODS

Ten healthy men (age: 25-28 years; body mass: 78.53 ± 5.5; height: 176.0 ± 6.54; BMI: 25.35 ± 2.67) participated in the study. They did not practice any sports and had used sauna baths very occasionally before. The research project was approved by the Ethical Committee of the Medical Academy in Cracow.

Subjects underwent a cycle of dry sauna bath (Exp I) and wet steam bath (Exp II) divided by a one-month break. Each bath lasted 60 minutes – 3 x 15 minutes in a sitting position in a hot chamber with 5-minute breaks between exposures. During breaks subjects cooled their bodies for 2 minutes with water of 22°C and after that they rested in a sitting position. The average temperature in the dry sauna was about 91°C with humidity of 5-18%, and 59°C in the wet sauna and 60.5% humidity. The body mass (BM) was determined by means of electronic scales (Type F1505-DZA; Sartourius Company, Germany) before entering the sauna and at the end of the thermal bath. Heart rate was measured by palpation on the carotid artery. Diastolic (DBP) and systolic (SBP) blood pressure were measured with a sphygmomanometer (Type Minimus II; Riester Company, Germany). Rectal temperature (Tre) was monitored by a thermocouple probe (Ellab, Denmark). Data were collected continuously using a medical precision thermometer (model CTF 9004; Ellab, Denmark) which measures temperature with an accuracy of 0.1°C. Heart rate was measured every 5 min during the sauna exposure. Diastolic and systolic blood pressure was measured before the bath and after three exposures. During the bath subjects estimated their thermal feelings by using a 7-point Bedford scale. To evaluate heat stress level two indexes were calculated.

The first one, the physiological strain index (PSI), is based on changes in rectal temperature (Tre) and heart rate (HR). The index rates the physiological strain on a universal scale of 0-10 and is calculated as follows:

$PSI = 5(T_{ret} - T_{re0}) \cdot (39.5 - T_{re0})\ 1 + 5(HR_t - HR_0) \cdot (180 - HR_0)^{-1}$

Where Tret and HRt are measurements taken at any time during the exposure and Tre0 and HR0 are the initial measurements [17].

The second index (CHSI), proposed by Frank et al. [4], describes physiological strain as a proportional contribution of circulatory and thermoregulatory loads. The CHSI index reflects the dynamics of changes in both components. It takes into account both thermoregulatory strain, which is described by the area under the hyperthermic curve, and circulatory strain, which is characterized by heart beat count over the basic level.

The CHSI index is calculated as follows:

$$CHSI=\left[\sum_0^t hb-\int_{c0}\cdot t\right]\cdot 10^{-3}\cdot\left[\int_0^t T_{re}\cdot dt-T_{re0}\cdot t\right]$$

Where $\left[\sum_0^t hb-\int_{c0}\cdot t\right]$ is accumulation of all heart beats during the exposure time, over the initial heart rate prior to exposure. The second part $\left[\int_0^t T_{re}\cdot dt-T_{re0}\cdot t\right]$ is calculated similarly, except that the temperature is a continuous measure and thermoregulatory strain is calculated as an integral.

*Statistical analysis*

The obtained data are presented as mean arithmetic values ± SD. We used repeated measures design analyses of variance (ANOVA) to evaluate the effect of sauna type on different parameters. We used the Tukey test for post-hoc comparisons in order to check which variables are particularly different from each other. Correlations between observed variables were calculated by Spearman's coefficient of rank correlation. A $p<0.05$ was considered statistically significant for all tests. All the calculations were done using the Statistica 8.0 package.

**TABLE 1.** CHANGES OF PHYSIOLOGICAL VARIABLES AFTER DRY AND WET SAUNA

| | Dry sauna | | | Wet sauna | | |
|---|---|---|---|---|---|---|
| | Before | After | Δ | Before | After | Δ |
| BM (kg) | 78.53 ± 5.53 | 77.81 ± 7.43 | -0.72* | 78.36 ± 7.53 | 78.0 ± 7.58 | -0.36*† |
| Tre (°C) | 36.89 ± 0.13 | 38.05 ± 0.08 | 1.16* | 36.89 ± 0.12 | 38.5 ± 0.11 | 1.61*† |
| HR (beats·min$^{-1}$) | 66.6 ± 2.84 | 126.0 ± 2.49 | 59.4* | 66.2 ± 2.28 | 138.2 ± 1.99 | 72.0*† |
| SBP (mmHg) | 122.6 ± 6.79 | 142.6 ± 4.96 | 20.0* | 123.4 ± 7.78 | 141.1 ± 8.56 | 17.7*† |
| DBP (mmHg) | 78.7 ± 5.72 | 63.7 ± 5.29 | -15* | 77.7 ± 4.76 | 57.7 ± 4.16 | -20*† |
| PSI | | 4.83 ± 0.29 | | | 5.70 ± 0.28† | |
| CHSI | | 76.30 ± 18.4 | | | 144.6 ± 21.7† | |

Note: *p ≤ 0.01 – after vs. before sauna bath, †p ≤ 0.05 – dry vs. wet sauna, BM – body mass, Tre – rectal temperature, HR – heart rate, SBP – systolic blood pressure, DBP – diastolic blood pressure, PSI – physiological strain index, CHSI – cumulative heat strain index

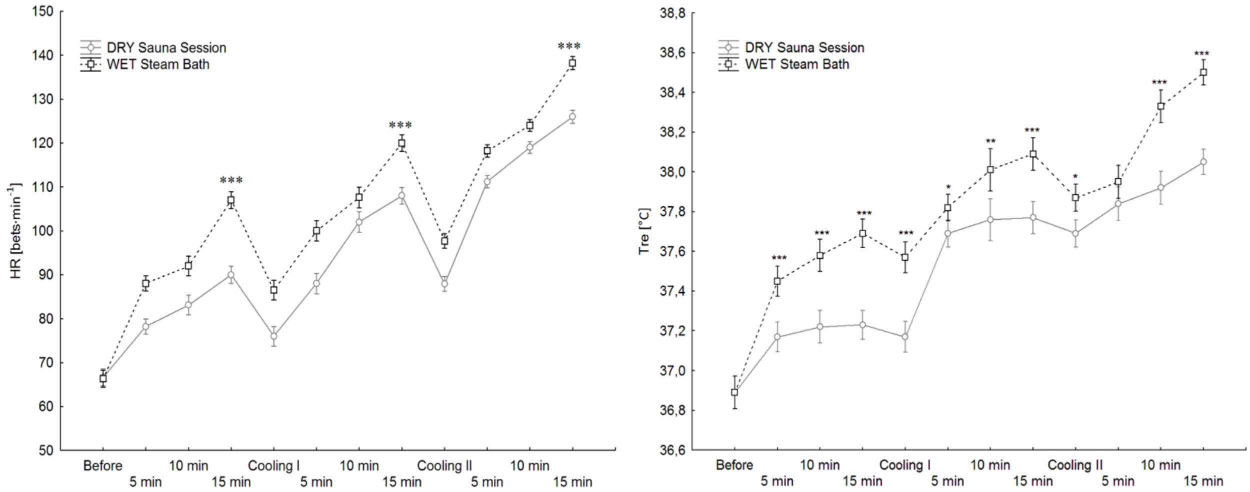


**FIG. 1.** HEART RATE AND RECTAL TEMPERATURE CHANGES IN DRY SAUNA SESSION AND WET STEAM BATH
Note: * $p<0.05$; *** $p<0.001$.

## RESULTS

Body mass changes caused by hyperthermia are presented in Table 1. In the examined groups average body mass loss was 0.72 kg after dry sauna and 0.36 after wet sauna bath. Both changes were statistically significant ($p<0.01$). Body mass loss was two times higher after dry sauna than after wet one ($p<0.05$). Rectal temperature increased by 1.16°C after dry ($p<0.01$) and by 1.61°C after wet sauna ($p<0.01$) (Table 1; Fig. 1). The increase of the rectal temperature was higher during the bath in the wet sauna in comparison to the dry one ($p<0.01$) (Fig. 1). During both baths (dry and wet) the HR increased by 59.4 and 72 beats·min$^{-1}$ respectively ($p<0.01$). The systolic blood pressure increased by 20 mmHg ($p<0.01$) during the dry, and by 17.7 mmHg ($p<0.05$) in the wet sauna (Table 1). Diastolic pressure decreased by 15 mmHg ($p<0.01$) in the dry, and by 20 mmHg ($p<0.01$) in the wet sauna ($p<0.01$). The increase of systolic pressure was higher during the dry sauna bath ($p<0.05$), whereas the diastolic pressure decreased more during the wet sauna ($p<0.01$). The subjective estimation of heat comfort (Bedford's scale) indicates that the heat discomfort is greater in the wet sauna especially during the last phase of exposure (Fig. 2). The physiological strain index (PSI) and cumulative heat strain index (CHSI) were also greater during the wet sauna session (Fig. 3; Table 1). Significant differences were observed from the first entrance in the PSI index and from the second entrance in the CHSI index (Fig. 3). In both baths indexes were significantly correlated during all entrances with each other ($r=0.87$). With Bedford's scale indexes were significantly correlated only for the third entrance ($r=0.64$ for PSI; $r=0.54$ for CHSI).

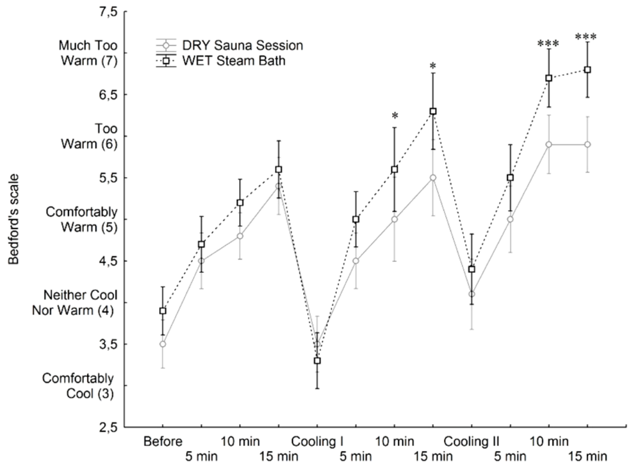


**FIG. 2.** HEAT COMFORT ESTIMATED BY BEDFORD'S SCALE IN DRY SAUNA SESSION AND WET STEAM BATH
Note: * $p<0.05$; *** $p<0.001$.

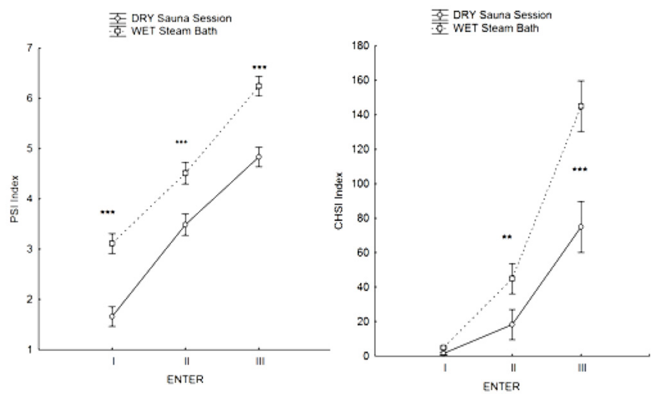


**FIG. 3.** PSI AND CHSI INDEX CHANGES IN DRY SAUNA AND WET STEAM BATH
Note: ** $P<0.01$; *** $P<0.001$.

## DISCUSSION

Core temperature increases rapidly during a sauna bath because heat influences two large surfaces: skin and epithelium of pulmonary alveoli. Elevated core temperature triggers a number of thermoregulatory reactions which prevent overheating. Under the specific conditions of sauna the only efficient way of reducing body temperature is vaporization of sweat from the skin. This leads to reduction of body water, body mass and plasma volume [2]. During the routine sauna bath the average loss of water is at the level of 400-600 g [11-13,21,22]. The loss of water corresponds to a reduction of body mass, which is significantly lower for women than for men because women contain less body water and more fat tissue [21,22]. There are also some differences in thermoregulatory mechanisms in men and women, e.g. different dynamics of sweating depending on the phase of the menstrual cycle, which may be responsible for smaller body loss during body heating in women than in men [6,24,25]. The average losses of body mass for men were 0.72 kg in the dry sauna and 0.36 in the wet sauna. The research showed that there were significant differences in body mass loss dependant on the environment where the research was carried out. These differences result from the fact that the vaporization ratio decreases when the humidity of the environment and skin increases. The effectiveness of sweating when the skin is moist is decreased because of the layer of sweat on the skin, which influences the sweat glands. The ratio of evaporated sweat to excreted sweat is very important for the efficiency of thermoregulation. High humidity of the skin slows down the speed of excretion and evaporation of sweat. In the wet sauna there is high moistness of the skin as well as droplet loss of sweat, which does not lower the temperature of the organism [6,7]. When the exposure to heat is extended even the most efficient mechanisms cannot stop the accumulation of heat in the organism. The measurements show progressive increase of internal temperature. In the wet sauna the rectal temperature was higher than in the dry sauna. This was connected with lower dehydration and sweating, which affects the accumulation of heat in the body. In these experiments the rectal temperature increased in both groups. However, a greater increase was observed during the wet sauna session.

The organism reacts to high temperature by dilatation of skin vessels and by increasing blood flow through the skin. During extreme situations skin blood flow may by elevated even to 60% of cardiac output [29,31]. Elevated skin blood flow may be continued due to reduced flow in different vessels. Muscle, kidney and visceral blood flow is reduced. Cardiac output may be increased by 6.6 l/min due to increased heart rate. Stroke volume remains constant or increases a little [16,19,20,27]. Increased heart rate is a result of activation of the sympathetic nervous system and secretion of noradrenalin [8,9,12]. Hyperthermia reduces peripheral resistance by dilatation of metarterioles, arterioles, precapillary arterioles and artery-vein anastomosis. A typical Finnish bath causes an increase of heart rate from 100 to 160 beats per minute [10,16,27]. In this experiment during heat exposure the heart rate increased to 126 beats per minute in the dry sauna and to 138 beats per minute in the wet one. The higher increase of heart rate in the wet sauna is connected with reduced possibility to exchange heat with the high humidity environment.

Data about the changes of systolic pressure of blood are ambiguous. Generally it is said that systolic pressure elevates a little during a sauna bath [16]; however, some researchers report that systolic pressure may decrease during a long sauna bath [14]. Diastolic pressure usually decreases [16], which may result in syncope, especially when the body position is changed rapidly. A decrease or increase of systolic pressure depends on changes in peripheral resistance and on compensation by increase of cardiac output [15]. Systolic pressure may increase when water is poured on the stones, which raises the humidity, or when the body is rapidly cooled, for example under a cold shower. This situation leads to sudden vasoconstriction of the skin, to a rise of blood pressure, and to a reflex decrease of heart rate [16,18]. That is why people with hypertension should avoid sudden cooling after a sauna bath [10,31]. In men who took part in the experiment the systolic pressure after wet and dry sauna did not differ much. Systolic pressure increased by 20 mmHg in the dry sauna and 18 mmHg in the wet sauna. These results are similar to earlier experiments where the average increase of systolic pressure was between 15 and 25 mmHg [26,30]. Diastolic pressure decreased in both saunas, but in the wet sauna the decrease of DBP was greater.

Mental changes due to the heat are not entirely explained. In this experiment during the heat exposure the thermal sensation was measured with a 7-degree Bedford scale. The tolerance for heat in men was better in the environment of high temperature and low humidity (dry sauna), whereas in the environment of lower temperature and high humidity the tolerance was much lower.

To assess physiological heat strain experienced by subjects undergoing a sauna bath we use two different heat strain indexes: PSI and CHSI. Both indexes are used for assessing the magnitude of heat strain during physical efforts in various thermal situations. In this study we used them for the first time to assess the magnitude of heat strain during passive heating in dry and wet sauna baths. Both indexes were elevated during sauna bathing, but greater increases were observed during bathing in a wet sauna. Only in the third entrance during the sauna bath were thermal strain indexes significantly correlated with thermal discomfort expressed by a high score on the Bradford scale. While the Bedford thermal scale is a good but subjective indicator of heat comfort, both studied indexes could be objective indicators of heat strain during passive body heating.

## CONCLUSIONS

To conclude, the wet sauna where the humidity is higher causes a much greater load of heat for the organism compared to the dry sauna bath. This is evidenced by greater increase of rectal temperature, greater increase of heart rate, by intensive subjective sensation indicated, and by a greater physiological strain index during bathing in the wet sauna. It can be concluded that both indexes, PSI and CHSI, may be useful for objective assessment of heat strain magnitude during passive heating of the organism.

**Conflict of interest:** none declared.

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