Original Article

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Effect of repeated alternative thermal stress on the physiological and body composition characteristics of young women sporadically using sauna

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Abstract

Aim: The aim of this study was to determine the effect of repeated alternative thermal stress on the physiological parameters of young women sporadically used sauna. *Materials and method:* Twenty young women (age: 24.2±2.1 years) were exposed to four sauna sessions of 12 minutes each (temperature: 90-91°C; humidity: 14-16 %) with four 6-minute cool-down breaks including 2-minute cold water immersion (temperature: 9-11°C). Physiological characteristics were monitored before and after the 72-minute experiment. Systolic and diastolic blood pressures (systolic - SBP, diastolic - DBP), heart rate (HR), forehead temperature, and body composition were determined on each subject and dependent t-test were performed on each variable. *Results:* During the 72-minute experiment forehead temperature increased significantly (p<0.001). A significant decrease was observed in DBP (p=0.045), body mass (p<0.001), minerals (p=0.01), body fat mass (p=0.035), BMI (p<0.001), waist to hip ratio (p=0.042), visceral fat level (p=0.004) and obesity degree (p=0.044) during four successive 12-minute sauna sessions. *Conclusions:* Seventy-two minutes of alternating (hot and cold) repeated thermal stress has a significant effect on significant decrease in the values of DBP, and body composition (body mass, BMI, BFM and minerals) characteristics. Two-minute cold water immersions allow the body to cool down significantly and gives the opportunity to stay in the sauna for longer time. Long stays in the sauna can be used to reduce levels of body fat in the human body.

Keywords: Finnish sauna, alternative environment, university female students; physiological effects, body composition

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INTRODUCTION

The influence of saunas on the human body remains a topic of relatively high interest among health scientists. As indicated by Hussain and Cohen [1] this is a form of whole-body thermotherapy that has been used in various forms (radiant heat, sweat lodges etc.) for thousands of years in many parts of the world for hygiene, health, social, and spiritual purposes. The human body has a limited capability for adapting to alternating exposure to heat and cold, and for this reason, thermal stress is typically thought to present a challenge to human health and homeostasis [2]. On the other hand, Finnish sauna bathing plays a role in preventing cardiovascular and all-cause mortality, sudden cardiac death (SCD), dementia, and Alzheimer's disease [3,4]. It has been also suggested that heat stress induces adaptive hormesis mechanisms similar to exercise, and there are reports of cellular effects induced by whole-body hyperthermia in conjunction with oncology-related interventions (i.e., chemotherapy and radiotherapy) [5, 6]. This may be because the Finnish sauna environment has unique features that make it difficult to directly compare with other methods of heat therapy [7]. Finnish saunas are characterized by relatively high temperatures (80–100°C) and dry air that circulates well, making it easier to tolerate and even enjoy the high temperatures within them. Regular sauna use by healthy individuals [8,9], persons with health problems [10-12] and athletes [13, 14] exerts beneficial effects as a form of heat therapy and biological regeneration, although this phenomenon does not occur in all cases. Example of research questioning the validity of using a sauna after heavy strength training, as well as 24 hours before the next training session are the results achieved by Rissanen et al. [15].

The protective effects of the Finnish sauna may reflect the fact that it is a regular life-long habit. Thus, the benefits derived from sauna use in Finland may differ from those obtained by short-term or temporal heat stress activities. For example, sauna use is not as popular in Poland as it is in the Scandinavian countries. The vast majority of adult Poles use saunas relatively infrequently and perhaps that is why a certain percentage of them do not feel comfortable in a sauna [16,17]. In contrast to the Pole a typical Finn takes sauna baths at least once a week, averaging about twice a week [3]. Sauna bathing begins very early in childhood, as children that are only 0.5–1-years old are gradually introduced saunas. For example, the results of a study conducted by Jokinen et al. [18] of 5 – 10-year-old children revealed that maintenance of homeothermia resulted in moderate hormonal changes in children regularly using Finnish sauna during thermal stress which indicate similar adequate hormonal thermoregulatory adjustment as previously documented in adults. The response to thermal stress of never or occasional sauna users and sedentary lifestyle people is different, with physiological processes occurring more dynamically in the body [19] when compared to physically active and regular sauna users [9,20]. The phenomenon of increased metabolic processes associated with maintaining constant body temperature under heat stress is also more pronounced in people who are overweight or obese [21,22].

It is also worth recalling, that sauna bath consists of repeated cycles of exposure to heat and cold, and due to this fact the length of stay in hot room and cold pad depends on each bather's own sensations of comfort [23]. Time proportions of alternating hot and cold environments intensify or inhibit metabolism respectively [24], which is not insignificant for the length of the sauna sessions used. Research conducted on young people revealed, that repeated and prolonged thermal stress increases physiological processes in the human body [12,21]. Therefore, in order to prolong sauna sessions, the cooling process of the body should be extended and intensified by cold/ice water immersion [25], which will slow down the metabolism [26]. As yet, it has not been determined exactly how long the body should be cooled down in the cold/ice water after it has been pre-heated so that it can be reheated during the next sauna session, and what the temperature and time proportions of the heating and cooling phases should be.

The aim of this study was to determine the effect of repeated alternative thermal stress on physiological and body composition parameters of young women with moderate level of physical activity. From a practical point of view, an attempt was made to investigate whether 2-minute cold water immersions provide the opportunity for occasional female sauna users to stay longer in the sauna.

MATERIALS AND METHODS

Participants Selection

The study was conducted on 20 full-time volunteer female students aged 18-27 years (24.2±2.09). The pool of potential participants were informed about the purpose of the study during obligatory classes of physiology at the University of Warmia and Mazury in Olsztyn (UWM). The students who agreed to participate in the study (24 women) were notified by e-mail and text message whether they met the inclusion criteria and were provided with the date of final recruitment. Twenty female university students meeting the inclusion criteria were recruited for the study. The participants confirmed that they did not take any medications or nutritional supplements, were in good health, and had no history of blood diseases or diseases affecting biochemical and biomechanical factors. None of the evaluated participants had respiratory or circulatory ailments.

Physical activity (PA) levels (quantitative analysis) were evaluated with the use of the Polish short version of the standardized and validated International Physical Activity Questionnaire (IPAQ) [27]. The IPAQ was used only to select a homogenous sample of female students, and the results were presented only in terms of metabolic equivalent of task (MET) units indicative of the participants' PA levels. The participants declared their average weekly number of minutes dedicated to PA (minimum of 10 minutes) before the study. The energy expenditure associated with weekly PA levels was expressed in terms of METs-min/week [28]. The MET is the ratio of the work metabolic rate to the resting metabolic rate, and 1 MET denotes the amount of oxygen consumed in 1 minute, which is estimated at 3.5 mL/kg/min. Based on the declared frequency, intensity and duration of PA, the respondents were classified into groups characterized by low (< 600 METs-min/week), moderate (600 to 1500 METs per week) and high (≥ 1,500 METs-min/week) levels of activity. Only female students characterized by moderate levels of PA and who had sporadically (1-3 times in their life) used a sauna were chosen for the study.

Instruments and procedures

The participants received comprehensive information about sauna rules preceding the study. They were asked to drink at least 1 L of water on the day of the test and 0.5 L of water 2 hours before the session. The participants did not consume any foods or other fluids until after the final body measurements when the experiment was completed. All participants visited a dry sauna in the same location and during the same period (between 8:00–10:00 AM) to minimize the effect of diurnal variation on the results. Every participant attended four sauna sessions (temperature: 90°C; relative humidity: 14–16%) of 12 min each and remained in a sitting position during each session. After every 12-min session, students recovered in a neutral room (temperature of 18°C and relative humidity 40–50%) in a sitting position. Each recovery session lasted 6 min, during which the participants remained in a cold paddling pool (water temperature: 9–10°C) for 2 min (body immersion up to the neck). The entire experiment lasted 72 minutes (72-ME = 4x12 min of heating + 4x6 min of cooling). The air temperature and humidity inside the sauna cabin and the neutral room and the water temperature in the paddling pool were measured with a Voltcraft BL-20 TRH + FM-200 hygrometer (Voltcraft Engineers Private Limited, Varanasi, India) and confirmed with a Stalgast 620711 laser thermometer (Stalgast sp. Z o.o., Radom, Poland).

Body height was measured to the nearest 1 mm with a calibrated Soehlne Electronic Height Rod 5003 (Soehlne Professional, Germany), which communicated with an InBody 720 body composition analyzer (InBody Poland, Białystok, Poland). Before the first sauna session anthropometric characteristics, including body mass, body mass index (BMI), body surface area (BSA), and waist-hip ratio (WHR) were determined by bioelectrical impedance [29] with the InBody 720 body composition analyzer. Likewise, the same equipment was used to determine body composition measurements, including total body water (TBW), protein and mineral content, body fat mass (BFM), fat-free mass (FFM), skeletal muscle mass (SMM), percent body fat (PBF), InBody score, target weight, visceral fat level (VFL), basal metabolic rate (BMR), and degree of obesity. Before performing the second body composition analysis (after the experiment), the subjects had to dry their bodies very well, for which terry towels were used. At the end of the experiment, measurements of body mass were repeated with the use of InBody720.

Due to the high temperature in the sauna, physiological measurements during the experiment, including heart rate (HR minimum, average, peak), energy expenditure during the 72-ME (in kcal), estimated values of oxygen uptake (VO_2 average, max), excess post exercise oxygen consumption (EPOC average, peak), respiratory rate (RR average, max) and physical effort (based upon a range of heart rates), were assessed indirectly using heart rate monitors (Ambit3 Peak, Suunto Sapphire, Vantaa, Finland), which are widely used in studies of this type [12, 21]. These monitors were placed on the wrist with HR sensors attached to the chest. Before sauna exposure, every HR monitor was programmed for female sex, year of birth, body mass, and PA level. Physiological measurements were performed prior to the first entry to the sauna and the end of the fourth 6-min cooling period (72nd minute of the experiment). Blood pressure (BP) was measured with an automatic digital blood pressure monitor (Omron M6 Comfort. Tokyo, Japan). Forehead temperature with the use of non-contact clinical thermometer Buerer FT90 (Buerer Medical GmbH, Söflinger, Germany) as well as, BP and HR measurements were repeated immediately after the fourth cool-down break in the neutral room.

Statistical analysis

Basic descriptive statistics (mean, SD and range of variation) were calculated for each parameter, and the normality of distribution (asymmetry coefficient) was examined. All tested parameters had normal distribution, so the Student's t-test for dependent samples was used to assess the significance of differences between the arithmetic means of examined parameters before and after sauna. The calculations were performed using Statistica13 software at a significance level of $\alpha = 0.05$.

RESULTS

The mean values of physical activity (PA) levels were within the "moderate" level at 840±161.3 METs-min/week, whereas the minimum values were very close to the lower limit of the range (605 MET-min/week), as opposed to maximum values (1140 MET-min/week). The results regarding the values of physiological characteristics that occurred in the female subjects during the 72-minute session of alternating hot air and cold water (72-ME) are shown in Table 1.

Table 1. Mean values of selected physiological parameters in female subjects during sauna (72-ME)*

Physiological characteristics	During 72-ME			
	Mean	*SD*	Min	Max
HR_{avg} [bpm]	109.95	9.28	93	131
HR_{min} [bpm]	73.2	8.50	58	87
HR_{max} [bpm]	152.45	12.93	131	176
Energy expenditure [kcal]	578.4	114.51	383	799
VO_{2avg} [mL/kg/min]	15.9	2.86	12	23
VO_{2max} [mL/kg/min]	32.4	5.90	25	45
$EPOC_{avg}$ [mL/kg/min]	13.3	9.17	5	38
$EPOC_{peak}$ [mL/kg/min]	27.4	21.61	7	83
Respiratory $rate_{avg}$ [brpm]	19.8	2.3078	15	25
Respiratory $rate_{max}$ [brpm]	32	6.5212	25	46
Physical effort's intensity [s]				
Easy <107 [bpm]	1966.00	812.85	352	3417
Moderate 107-124 [bpm]	1369.90	280.99	831	1781
Difficult 125-141 [bpm]	691.55	487.19	72	1644
Very Difficult 142-159 [bpm]	232.45	265.44	0	804
Maximal ≥ 160 [bpm]	60.15	139.16	0	537

Notes: * - 4 x 12-minuteheating sessions + 4 x 6-minute cooling down, brpm – breaths per minute

Table 2. Values of selected physiological parameters before and after 72-ME.

Physiological characteristics	Before sauna				After sauna				*D*	*t*	*p*
	Mean	SD	Min	Max	Mean	SD	Min	Max			
SBP [mmHg]	124.45	17.77	93	154	119.15	14.35	98	156	5.30	1.75	0.096
DBP [mmHg]	75.15	9.52	53	91	72.05	7.48	54	85	3.10	2.15	0.045
HR [bpm]	92.05	13.17	65	117	89.90	9.32	68	109	2.15	1.19	0.248
Temperature [^{o}C]	36.74	0.48	35.6	37.8	37.82	0.73	36.8	39	-1.08	-6.29	<0.001

Notes: D – differences in numerical values

Table 3. Differences in the values of body composition characteristics before and after sauna

Anthropometric characteristics	Before sauna		After sauna		*D*	*t*	*p*
	Mean	SD	Mean	SD			
Body height	166.49	4.69	The same		Not applicable		
Body mass [kg]	67.84	19.88	67.55	19.87	0.29	6.250	>0.001
TBW [L]	33.27	4.32	33.21	4.39	0.06	0.416	0.682
Proteins [kg]	8.90	1.21	8.95	1.20	-0.06	-1.813	0.086
Minerals [kg]	3.20	0.36	3.15	0.33	0.05	2.839	0.010
BFM [kg]	22.53	15.38	22.15	15.44	0.37	2.267	0.035
FFM [kg]	45.31	5.87	45.48	5.83	-0.18	-1.046	0.3087
SMM [kg]	24.86	3.60	24.99	3.56	-0.13	-1.310	0.2058
BMI [kg/m^2]	24.490	7.0528	24.40	7.03	0.08	4.677	<0.001
PBF [%]	30.57	10.614	30.07	10.81	0.49	1.748	0.0965
In Body Score	69.90	10.56	70.20	10.66	-0.30	-1.064	0.3006
Target weight [kg]	61.86	5.56	61.80	5.52	0.06	0.838	0.4123
Weight control [kg]	-5.97	15.89	-5.83	15.85	-0.14	-1.594	0.1272
BFM control [kg]	-8.40	14.46	-8.14	14.48	-0.26	-1.654	0.1144
FFM control [kg]	2.43	2.77	2.28	2.68	0.15	1.063	0.3012
BMR [Kcal]	1348.85	127.02	1352.65	126.05	-3.80	-1.042	0.3101
WHR	0.88	0.06	0.87	0.06	0.01	2.179	0.042
VFL [kg]	9.40	6.62	8.90	6.51	0.50	3.249	0.004
Obesity degree	113.75	32.89	113.00	32.48	0.75	2.161	0.044

The average heart rate (HR_{avg}) for the subjects were 109 bpm which in a resting condition considered high as values greater than 100 bpm associated with tachycardia. Also the mean values of HR_{max} ranked at the upper limit of 'difficult intensity', and their highest value (176 bpm) was in the range of “maximal intensity”. The average energy expenditure during the 72-ME was 578.4 Kcal, peak oxygen uptake (VO_{2max}) was 32.4 mL/kg/min, and excess post-exercise oxygen consumption ($EPOC_{peak}$) was 27.4 mL/kg/min. During entire the 72-ME, subjects performed an average of 20 breaths per minute (brpm), with the maximum number of 32 brpm during heat exposure. In terms of maximal intensity efforts, the subjects lasted just over a minute. The average HR values were close to the lower limit of "moderate intensity" and in this range women stayed the longest during the whole measurement (1369.9 s).

Table 2 shows the differences in blood pressure (SBP, DBP), HR and forehead temperature before and after 72-ME (including the final cooling section period). Among the physiological characteristics studied, there was a significant ($p=0.045$) decrease in the DBP of 3.1 mmHg and significant ($p < 0.001$) increase by 1.1^{o}C of forehead temperature. The SBP decreased from 124.5 to 119.2 mmHg with a difference of 5.3 mmHg, while HR decreased from 92.1 to 89.9 bpm however these changes were not significant ($p > 0.5$).

Table 3 shows the changes that occurred in the anthropometric characteristics studied under alternating thermal stress (72-ME). A significant decrease in values occurred for the following characteristics: body mass (D=0.29 kg, $p<0.001$), BFM (D=0.37 kg, p = 0.035), and BMI (D=0.08 kg/m^2, $p<0.001$), WHR (D=0.01, p= 0.042), VFL (D= 0.5 kg, p=0.004), and obesity degree (D=0.75, p=0.044).

DISCUSSION

The purpose of the present study was to determine changes in physiological and body composition characteristics in young women under 72-minutes of heat and cold thermal stress (72-ME). The designed scheme of the study was also intended to answer for the question whether 2-minute cooling of the body by immersion in cold water (10 - 11^{o}C) allows the women to tolerate four 12-minute sauna sessions (temperature 90^{o}C, humidity 14 - 16%),

While in the sauna, the average values of heart rate (HR_{avg}) were within the lower limit of "easy" efforts, however the peak values of heart rate (HR_{max}) reached "very difficult" efforts. It can be assumed that during a 2-minute cooling down of these females in cold water, there was a marked slowdown of metabolic processes with a simultaneous slowdown of the heart rate. Such suppositions are also supported by HR values obtained immediately before the first 12-minute warm-up session and after the fourth 6-minute rest session, during which the women cooled down for 2 minutes. These values were slightly lower after 4 rest sessions compared to the values obtained immediately before entering the sauna (92.1 vs 89.9 bpm) however non-significant. Previous studies in young people who regularly use the sauna, show elevated heart rates increases to approximately 100-110 bpm and with higher ambient temperatures values that exceed 140-150 bpm [12, 30, 31]. In subjects who do not regularly use the sauna, these heart rate values might be even higher [32].

In terms of health outcomes, the increase in HR to around 120 bpm is regarded as a beneficial adaptive response, whereas an increase in excess of 140 bpm can have adverse consequences because it is associated with higher cardiac effort and diastole shortening [31]. Moreover, for the vast majority of the 72-minute experiment the subjects were in the "easy" and moderate" efforts HR range. Therefore, it can be assumed that the 6-minute rest phases during which the women's bodies were immersed in cold water for 2 minutes led to sufficient cooling of their bodies, reduction of HR and allowed the subjects to repeat the 12-minute sauna sessions 4 times at relatively high temperatures even though the subjects occasionally used the sauna. As a result of 72-ME, the subjects expended an average of 578.4 Kcal, which should be considered a very good result for women with moderate level of PA. The practice of training conducted with people characterized by moderate levels of PA shows that the one biggest problem is the ability of such people to continue their efforts for a relatively long time [34]. When designing a suitable weight loss program, exercise duration and intensity are generally manipulated. Training length, not intensity, is more important for fat burning [35]. At higher intensity workouts, a person expends more calories per minute (10 kcal per minute, for instance), and even though the percentage of fat calories expended is lower, the actual number of fat calories expended is higher [36,37]. From the point of view of people who are not very physically active (constituing the majority in the population) or not able to exercise intensively [38], finding a method to increase caloric expenditure without vigorous exertion is needed [39]. The present study showed that repeated alternative thermal stress can be used for such purposes.

The body mass of the women studied decreased significantly by 0.3 kg ($p<0.001$), however it should be mentioned for a 72-ME the subjects were not allowed to drink any fluids. Research conducted on sedentary students (326 women and 348 men) revealed that during two 10-minute sessions with 5-minute break (temp. 90 ^{o}C, humidity – 35%) the subjects lost approx.0.4 L, although the greatest body mass loss was reported in overweight and obese subjects [40]. In the case of research on young overweight sedentary men subjected to repeated thermal stress (temperature: 90°C, humidity: 15%) for 60 minutes 0.65 kg of bodily fluids on average [12]. Body composition analysis conducted in the present study showed that the women studied also lost 0.37 kg of BFM (p=0.035), and, as a result, their VFL also decreased significantly (p=0.004) by 0.75 kg. In a study involving young and physically active men subjected to 72-minute thermal stress under very similar conditions (temperature: 90°C, humidity: 14-16%) a significant ($p<0.001$) decrease in BP (SBP and

DBP) and body mass of 1.1 kg was shown, indicating that the level of PA and frequency of sauna use correlate significantly positively with body mass loss [20]. The results of the studies presented in this paper (concerning women) overlap and complement earlier studies conducted on young men. Despite significant ($p<0.001$) increase of forehead temperature, a significant decrease in DBP ($p=0.045$) but a non-significant decrease in SBP were observed. The alternate exposure of the human body to hot and cold environments may produce a health effect manifested, among other things, based on improvement of DBP. This health-positive phenomenon has been confirmed by many scientific studies presented in systematic review by Laukkanen et al. [7]. However, it should be mentioned that the effects of sauna bathing on BP reported in the literature vary considerably, depending on; the applied method of measurement, type of sauna, duration of exposure which elicits the evaporation effect, and user adaptation to high temperature. Considerable variations were reported in studies where BP was measured with a sphygmomanometer, ranging from a minor increase [23, 41] or the absence of any changes [42-45], to a decrease in SBP [46-48] and DBP values [11,30,32,49-51].

Based on the results obtained in the present study, and their comparison with studies published earlier can be concluded, that repeated alternative in the form of a Finnish sauna can have positive effects on the cardiovascular system. The present study showed that sufficiently prolonged thermal stress can be used as a supportive weight loss (slimming) factor in health (functional) training leading to improvement of motor fitness and human body composition characteristics. Such suppositions are confirmed by research conducted on young women and men during physical education lessons, in which a hybrid form of physical activity was offered to university students (women and men) consisting of jogging followed by sauna. That study showed that male students had the lowest body weight and BMI values than students engaged in other forms of physical activity. During the 60-minute class, there was a non-significant decrease in the values of these anthropometric characteristics, to significant improvement of motor fitness [52]. On the other hand, in the female university students studied, in addition to an improvement in motor fitness, there was a significant ($p<0.001$) decrease in the values of body mass and BMI [53,54]. Later studies in this area showed that jogging followed by sauna is one of the forms of physical activity (along with martial arts and swimming) characterized by the highest intensity among both men [55] and women [56].

Strength and limitations

The strength of the present study is its practical application among young people who want to stay in the sauna relatively longer, and thus also use it to improve body composition characteristics also including the loss of excess body fat. The use of Suunto Ambit3 Peak Sapphire heart rate monitors for measuring the participants' physiological parameters was a potential limitation of this study. It would be better to use indirect calorimetry to determine energy expenditure, however, due to the environment in which the females were exposed to was very high temperature (90°C) this type of instrumentation is prohibitive. Therefore, different measuring equipment could not have been used as effectively in a study conducted on a homogenous sample (20 females) with similar environmental conditions (day, hour, duration, temperature and humidity). Besides, estimated values of such parameters as VO_2 , EPOC and respiratory rates are also recognized in studies of this type [12,21].

It should also be mentioned that measurements of body composition using the electrical bioimpedance method must be carried out in a state of relative rest of the body (homeostasis). With thermoregulation to dissipate heat, some changes in the ratio of extracellular to intercellular might alter this condition. The values of HR obtained at the end of 72-ME were non-significantly lower than the initial ones, which may indicate that the bodies of the women studied were in such a state.

CONCLUSIONS

Seventy-two minutes of alternating (hot and cold) repeated thermal stress has a significant effect on lowering values of DBP, and body composition (body mass, BMI, BFM and minerals) characteristics. Two-minute cold water immersions used during the 6-minute break allow you to significantly cool the body and slow down metabolic processes, which gives you the opportunity to stay longer in the sauna with the simultaneous need to replenish fluids containing minerals. Relatively long stays in the sauna can be used to reduce the level of body fat in the human body.

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Institutional Review Board Statement

The study was conducted with the prior consent of the Ethics Committee of the University of Warmia and Mazury in Olsztyn (No. 10/2020), Poland.

Informed Consent Statement

It was performed with volunteers who signed an informed consent statement.

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Conflicts of Interest

All Authors declare that there is no conflict of interests regarding the paper and its publication

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