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CHANGES IN THE BLOOD PRESSURE, HEART RATE AND BODY MASS OF PHYSICALLY ACTIVE MEN IN RESPONSE TO THERMAL STRESS

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Abstract **Background:** Finnish sauna is presently the most popular type of thermal therapy in Europe. Saunas are widely available in aquaparks, SPA centers and hotels. In Scandinavian countries sauna is regarded not only as a form of treatment, but as a part of the national lifestyle.

Objective: The aim of this study was to evaluate sauna-induced changes in systolic (SBP) and diastolic blood pressure (DBP), heart rate (HR) and body mass in healthy men.

Methods: Thirty healthy men aged 20–49 years (mean age: 31.2 ±11.3 years) attended four 12-minute Finnish sauna sessions (temperature: 90°C, humidity: 14–16%) with 6-minute breaks in between sessions, including cold water immersion for 1 minute. The participants' physical activity (PA) levels were evaluated with an IPAQ questionnaire. Sauna bathers' body composition, BP and HR were measured before the first and after the fourth sauna session.

Results: A significant ($p < 0.001$) decrease in SBP and DBP values was noted in response to sauna regardless of the bathers' body mass, age and PA levels. The average HR increased significantly in younger, slimmer and more physically active participants. Sauna treatment induced a significant decrease in body mass loss regardless of all independent variables.

Conclusions: Repeated 12-minute Finnish sauna sessions have a beneficial influence on the cardiovascular system. Finnish sauna can be recommended for healthy men with average and high PA levels as a means of decreasing BP. Body mass loss, on the other hand, is related to the loss of body fluids as a result of sweating.

Key words dry sauna, blood pressure, heart rate, body mass loss, physical activity

Introduction

Finnish sauna is presently the most popular type of thermal therapy in Europe. Saunas are widely available in aquaparks, SPA centers and hotels, and the average admission fee is not high. In the Scandinavian countries, sauna is regarded not only as a form of treatment, but as a part of the national lifestyle (Perasalo, 1988). A visit to the sauna is a social and recreational activity during which the participants enjoy the company of others (Leung, 2017). There is evidence to indicate that regular sauna users have a longer life expectancy than sporadic sauna-goers (Laukkanen, Khan, Zaccardi, Laukkanen, 2015). According to bathers, the main benefits of sauna include stress reduction, improved sleep quality and decrease in chronic pain (Hussain, Greaves, Cohen, 2019). Regular sauna bathing minimizes the risk of modern lifestyle diseases, including overweight and cardiovascular diseases (Hannuksela, Ellahham, 2001; Kukkonen-Harjula, Kauppinen, 2006; Borysławski, Szaliłow, Bielec, Omelan, Podstawski, 2021).

Sauna bathing induces changes in circulation by enhancing blood flow to subcutaneous tissues. Heat accumulated in the body is released during sweating, which lowers blood pressure and increases the heart rate (HR) (Crandall et al., 2008; Pippi, Bini, Reginato, Aiello, Fanelli, 2021). Despite the fact that sauna is not recommended for individuals with cardiovascular diseases, it seems that sauna bathing improves hemodynamic parameters, clinical symptoms and cardiac function in patients diagnosed with congestive heart failure (Blum, Blum, 2007). A review of the literature suggests that controlled exposure to high temperature with low air humidity improves other cardiovascular functions by increasing left ventricular ejection function and considerably decreasing systolic blood pressure (SBP) (Crinnion, 2011). Regular sauna use also enhances the protective functions of the skin by maintaining a healthy pH and water holding capacity of the stratum corneum (Kowatzki et al., 2008). Sauna's effect on body mass loss is ambiguous. A single 30-minute session in a Finnish sauna did not induce significant changes in the body mass of healthy young men with both high and low PA levels (Żychowska, Półrola, Chruściński, Zielińska, Góral-Półrola, 2017). In young and physically active men, significant changes in body mass, body fat and BMI were not reported after ten Finnish sauna sessions (Gryka, Pilch, Szarek, Szyguła, Tota, 2014). In contrast, two 10-minute sauna sessions were found to decrease body mass in young sedentary women and men (Podstawski et al., 2014). The same study also revealed that individuals with high BMI values and high body fat percentage lost more body mass during sauna than lean bathers. The aforementioned studies present different protocols concerning the time of heat exposure in the sauna and the recovery mode. To the best of our knowledge, this is the first study to examine the effect of four 12-minute sauna sessions with a mixed recovery protocol.

Therefore, the aim of this study was to evaluate changes in selected physiological parameters in 30 young and middle-aged healthy men subjected to repeated thermal stress in a sauna. The authors hypothesized that sweating and thermoregulation processes during repeated sauna sessions would increase the HR, promote the loss bodily fluids and therefore decrease the participants' body mass.

Methods

Participants

The study involved 30 men aged 20–49 years (mean 31.2 ±11.31 years) with average and high physical activity (PA) levels. They were selected from a pool of volunteers (47 men) who were informed about the purpose of the study. The candidates were notified by e-mail and text message whether they met the inclusion criteria and were provided with the date of final recruitment. In order to adapt to a relatively high physiological load caused by thermal stress, the candidates visited the sauna 10 times (twice a week) in the period preceding the experiment. During each visit, they attended three 10-minute sauna sessions (temperature: 90°C, relative humidity: 14–16%) with 6-minute breaks in between sessions.

The participants were asked to complete a health questionnaire before the study. Thirty men meeting the below 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. The evaluated subjects presented medical certificates confirming that none of them had respiratory or circulatory ailments. Their PA levels were evaluated using the standardized and validated International Physical Activity Questionnaire (IPAQ) (Lee, Macfarlane, Lam, Stewart, 2011). In the overall group of 30 participants, 21 men were characterized by moderate PA levels (>600 METs per week) and 9 men – by high (>1,500 METs per week) PA levels based on self-reported activity levels in the short IPAQ form covering the last 7 days preceding the study (Craig et al., 2003).

Ethics approval

The study was conducted upon the prior consent of the Ethics Committee of the University of Warmia and Mazury in Olsztyn (10/2020), Poland, and it was consistent with the provisions of the Declaration of Helsinki developed by the World Medical Association. The participants were volunteers who signed an informed consent statement.

Research protocol

The participants received comprehensive information about sauna rules during the meeting 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 sauna session. The participants did not consume any foods or other fluids until after the final body measurements.

All participants visited a dry sauna in the same location and in the same time of the day (between 8:00–10:00) 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 minutes each and remained in a sitting position during each session. Every 12-minute sauna session was followed by a 6-minute recovery period. The participants recovered in a neutral room (temperature of 18°C and humidity 40–50% in a sitting position) for five minutes. Then, the participants remained immersed in a cold paddling pool (water temperature: +10–11°C) for 1 minute. The entire experiment lasted 72 minutes (72-ME). Air temperature and humidity inside the sauna cabin and the neutral room and water temperature in paddling pool were measured with the Voltcraft BL-20 TRH + FM-200 hygrometer (Germany) and confirmed with the Stalgast 620711 laser thermometer (Poland).

Body height was measured to the nearest 1 mm with a calibrated Soehlne Electronic Height Rod 5003 (Soehlne Professional, Germany) according to standardized guidelines. Body mass (measured to the nearest 0.1 kg), BMI and body composition parameters (weight, total body water – TBW, body fat mass – BFM, fat-free mass – FFM, waist-hip ratio – WHR) were determined by bioelectrical impedance with the InBody 720 body composition analyzer (InBody Co., South Korea) (Gibson, Holmes, Desautels, Edmonds, Nuudi, 2008). Blood pressure (BP) and heart rate HR were determined with an automatic digital blood pressure monitor (Omron M6 Comfort. Japan) immediately before the first session and immediately after the fourth cool-down break (the entire experiment lasted 72 minutes – 72-ME) in the neutral room. Due to high temperature in the sauna, the estimated values of physiological parameters, including heart rate ($HR_{min.\ avg.\ peak}$), recovery time, energy expenditure, oxygen uptake ($VO_{2\ avg.\ peak}$), excess post-exercise oxygen consumption ($EPOC_{avg.\ peak}$), respiratory rate ($_{avg.peak}$) and physical effort (easy, moderate, difficult, very difficult, maximal), were measured indirectly with Suunto Ambit3 Peak Sapphire heart rate monitors (Suunto Oy, Finland) which are widely used in studies of the type (Podstawski, Borysławski, Laukkanen, Clark, Choszcz, 2019). Physiological parameters were measured between the first sauna entry and the end of the fourth 12-minute session (66-ME). Pulsometers were placed on the wrist, and HR monitor sensors were attached to the chest. Every pulsometer was calibrated to sex, year of birth, body mass, and PA level before sauna exposure.

Statistical analysis

Grouping variables (excluding age) were applied to split the analyzed physiological parameters into two separate groups based on the median values of:

- Age: 1) younger – 20–26 years (N = 19) and 2) older – 39–49 years (N = 11),
- PA levels (MET): 1) lower – up to 1,166 (N = 15) and 2) higher – above 1,166 (N = 15),
- BMI (kg/m^2): 1) slimmer – up to 26.7 (N = 15) and 2) more obese – above 26.7 (N = 15),
- FFM (kg): 1) lower – up to 70.1 (N = 15) and 2) higher – above 70.1 (N = 15),
- BFM (kg): 1) lower – up to 16.6 (N = 15) and 2) higher – above 16.6 (N = 15),
- WHR: 1) lower – up to 0.91 (N = 15) and 2) higher – above 0.91 (N = 15),
- Frequency of sauna use: 1) often – every two weeks or more frequently (N = 16) and 2) rarely – once a month or less (N = 14).

The significance of differences between categories was determined by Student's *t*-test for dependent variables. All analyzed parameters had normal distribution. Normality was verified with the Shapiro-Wilk test. The asymmetry coefficient (As) was also calculated.

Results

The average PA level in the studied group was 1,322.2 MET, and it approximated the upper limit of moderate PA levels (600–1,500 MET). Based on WHO standards, the participants' average BMI (26.7 kg/cm^2) was within the overweight range. The average WHR (0.9) was indicative of gynoid body type (Table 1).

A significant ($p < 0.001$) decrease in SBP (by 9.7 mmHg), DBP (by 6.9 mmHg) and body mass (by 1.0 kg), and a significant ($p < 0.003$) increase in HR (by 7.4 bpm) were noted in the studied population during sauna treatment (Table 2).

Table 1. Descriptive statistics of grouping variables before sauna treatment (N = 30)

Variable	Mean	*Me*	*SD*	min–max	*As*
Age (years)	31.20	24.00	11.31	20–49	0.64
MET, ml/kg BM/min	1,322.20	1,166.00	407.10	870–2045	0.62
TBW, l	51.43	50.90	6.04	40.2–62.8	–0.01
Body mass, kg	86.62	89.00	13.02	58.7–110.7	–0.29
Body height, cm	180.26	179.15	6.25	169.3–196.2	0.38
BMI, kg/cm2	26.66	26.70	3.76	17.4–34.1	–0.50
BFM, kg	16.74	16.60	6.66	4.0–32.9	0.23
FFM, kg	70.32	70.10	8.34	54.7–85.9	–0.04
WHR	0.90	0.91	0.07	0.72–1.03	–0.55

Table 2. Descriptive statistics of physiological parameters in the studied group (N = 30) before and after sauna treatment

Variable	Before sauna			After sauna			Difference	
	mean	*SD*	min–max	mean	*SD*	min–max	*t*	*p*
SBP, mmHg	134.63	12.95	107–155	124.93	12.04	105–156	6.61	<0.001
DBP, mmHg	78.20	12.05	53–113	71.27	9.76	50–91	4.85	<0.001
HR, bpm	74.57	12.99	50–111	82.00	13.59	61–119	–3.26	0.003
Body mass, kg	86.62	13.02	58.7–110.7	85.62	12.92	58.0–109.9	20.04	<0.001

Younger (Y) and older (O) men responded similarly to sauna (Table 3). In both age groups, the smallest changes were noted in HR values which increased significantly ($p < 0.004$) only in younger participants (by 9.2 bpm). The remaining physiological parameters decreased significantly in both age groups. A greater decrease in the absolute values of DBP (Y – 5.89 mmHg, O – 8.73 mmHg), SBP (Y – 9.31 mmHg, O – 10.36 mmHg) and body mass (Y – 1.38 kg, O – 1.74 kg) was observed in older men, but the differences in SBP and body mass were significant among younger participants due to a higher number of individuals in that group (Table 3).

Table 3. Descriptive statistics of physiological parameters in younger (N = 19) and older (N = 11) participants before and after sauna treatment

Variable	Age	Before sauna		After sauna		Difference	
		mean	*SD*	mean	*SD*	*t*	*p*
SBP, mmHg	Y	133.84	13.05	124.53	13.19	7.98	<0.001
	O	136.00	13.29	125.64	10.32	4.05	0.002
DBP, mmHg	Y	76.00	13.82	70.11	10.40	2.79	0.012
	O	82.00	7.20	73.27	8.64	6.54	<0.001
HR, bpm	Y	75.58	12.84	84.79	15.74	–3.28	0.004
	O	72.82	13.68	77.18	7.04	–1.12	*NS*
Body mass, kg	Y	85.88	15.42	84.50	15.34	22.24	<0.001
	O	87.90	7.77	86.18	7.67	10.74	<0.001

Notes: Y – younger, O – older, *NS* – no significant difference.

Greater changes in the analyzed parameters were generally noted in more physically active men (Table 4). The directions of the evaluated changes were consistent with the general trend regardless of the participants' PA levels. Heart rate values increased significantly (by 8.2 bpm, $p < 0.004$) in more physically active men (H), whereas the increase noted in less active men (L) was not significant ($p > 0.05$). The decrease in the measured values of SBP (L – 8.53 mmHg, H – 10.87 mmHg) and DBP (L – 7.74 mmHg, H – 7.13 mmHg) was significantly greater in participants characterized by higher PA levels, whereas the decrease in body mass was significant and highly similar in both groups (approx. 1.5 kg, $p < 0.001$).

Table 4. Descriptive statistics of physiological parameters in participants with lower (N = 15) and higher (N = 15) PA levels, before and after sauna treatment

Variable	PAL	Before sauna		After sauna		Difference	
		mean	*SD*	mean	*SD*	*t*	*p*
SBP, mmHg	L	135.00	12.93	126.47	13.52	3.82	0.002
	H	134.27	13.41	123.40	10.61	5.61	<0.001
DBP, mmHg	L	79.27	14.84	72.53	10.37	2.66	0.019
	H	77.13	8.82	70.00	9.30	5.00	<0.001
HR, bpm	L	78.00	14.28	84.67	13.10	–1.69	*NS*
	H	71.13	10.96	79.33	13.99	–3.39	0.004
Body mass, kg	L	88.31	12.55	86.78	12.55	15.21	<0.001
	H	84.93	13.69	83.45	13.51	12.90	<0.001

Notes: PAL – physical activity level, L – lower, H – higher, *NS* – no significant difference.

Table 5. Descriptive statistics of physiological parameters in slimmer (N = 15) and more obese (N = 15) participants before and after sauna treatment

Variable	BMI	Before sauna		After sauna		Difference	
		mean	*SD*	mean	*SD*	*t*	*p*
SBP, mmHg	S	127.67	8.79	118.00	8.98	6.21	<0.001
	F	141.60	12.89	131.87	10.80	3.82	0.002
DBP, mmHg	S	76.07	12.43	69.87	9.55	2.32	0.036
	F	80.33	11.68	72.67	10.10	6.85	<0.001
HR, bpm	S	70.00	10.21	79.93	12.13	–3.76	0.002
	F	79.13	14.16	84.07	15.05	–1.33	*NS*
Body mass, kg	S	77.29	9.98	75.93	9.89	19.45	<0.001
	F	95.95	8.06	94.30	8.21	13.19	<0.001

Notes: S – slimmer, F – fatter, *NS* – no significant difference.

The directions of changes in the values of BMI and FFM in more obese and slimmer men (BMI, Table 5) and in participants with low and high fat-free mass (FFM, Table 6) were also consistent with the general trend. With the exception of HR ($p > 0.05$) in more obese (F) individuals and subjects characterized by high FFM values (H), the noted changes were significant, but they were more pronounced in slimmer participants (Table 5 – S, Table 6 – H). Heart rate values increased significantly in men with lower BMI (S: increase of 9.93 bpm, $p < 0.002$) and lower FFM (L: increase of 11.6 bpm, $p < 0.001$). A greater decrease in the measured values of SBP, DBP and body mass was observed in more obese individuals (F): SBP – decrease of 9.73 mmHg; DBP – decrease of 7.66 mmHg; body mass – decrease of 1.65 kg; Table 5) and in individuals with lower fat-free mass (L: SBP – decrease of 11.13 mmHg; DBP – decrease of 7.46 mmHg; body mass – decrease of 1.58 kg; Table 6).

Table 6. Descriptive statistics of physiological parameters in participants with low (N = 15) and high (N = 15) values of FFM, before and after sauna treatment

Variable	FFM	Before sauna		After sauna		Difference	
		mean	*SD*	mean	*SD*	*t*	*p*
SBP, mmHg	H	125.53	10.28	117.27	10.04	4.38	<0.001
	L	143.73	8.01	132.60	8.58	4.94	<0.001
DBP, mmHg	H	74.87	14.01	68.47	10.05	2.41	0.030
	L	81.53	8.98	74.07	8.92	6.34	<0.001
HR, bpm	H	68.07	10.44	79.67	13.69	–4.46	<0.001
	L	81.07	12.24	84.33	13.54	–0.93	*NS*
Body mass, kg	H	76.99	9.91	75.56	9.75	14.36	<0.001
	L	96.25	7.35	94.67	7.43	14.03	<0.001

Notes: FFM – fat-free mass, L – lower, H – higher, *NS* – no significant difference.

The directions of changes in the analyzed parameters were also consistent with the general trend regardless of the participants' BFM (Table 7) and WHR values (Table 8). The observed changes were highly significant, excluding HR in men with lower values of BFM and WHR. Heart rate values increased significantly in men with higher BFM (increase of 7.66 bpm, $p = 0.023$) and higher WHR (increase of 9.87 bpm, $p < 0.009$). A greater decrease in the measured values of SBP was noted in participants with lower BFM (decrease of 10.34 mmHg) and WHR (decrease of 10.94 mmHg). The decrease in DBP was more pronounced in men with lower BFM (decrease of 7.0 mmHg) and higher WHR (decrease of 8.47 mmHg), whereas a greater decrease in body mass was noted in participants with higher BFM (decrease of 1.7 kg) and higher WHR (decrease of 1.5 kg).

Table 7. Descriptive statistics of physiological parameters in participants with low (N = 15) and high (N = 15) BFM values, before and after sauna treatment

Variable	BFM	Before sauna		After sauna		Difference	
		mean	*SD*	mean	*SD*	*t*	*p*
SBP, mmHg	L	129.27	10.48	118.93	11.05	5.36	<0.001
	H	140.00	13.26	130.93	10.05	4.00	0.001
DBP, mmHg	L	77.13	14.08	70.13	10.88	2.67	0.018
	H	79.27	10.00	72.40	8.74	5.41	<0.001
HR, bpm	L	72.07	13.62	79.27	12.84	–2.04	ns
	H	77.07	12.26	84.73	14.20	–2.54	0.023
Body mass, kg	L	78.31	11.18	76.98	11.10	19.19	<0.001
	H	94.93	8.84	93.25	8.99	14.05	<0.001

Notes: FFM – body-fat mass, L – lower, H – higher, *NS* – no significant difference.

Table 8. Descriptive statistics of physiological parameters in participants with low (N = 15) and high (N = 15) WHR values, before and after sauna treatment

Variable	WHR	Before sauna		After sauna		Difference	
		mean	*SD*	mean	*SD*	*t*	*p*
SBP, mmHg	L	130.47	13.17	119.53	11.49	4.75	<0.001
	H	138.80	11.69	130.33	10.28	4.59	<0.001
DBP, mmHg	L	74.60	11.78	69.20	11.68	3.99	0.001
	H	81.80	11.58	73.33	7.20	3.38	0.005
HR, bpm	L	70.33	14.92	75.33	10.31	–1.60	*NS*
	H	78.80	9.41	88.67	13.45	–2.99	0.009
Body mass, kg	L	80.08	11.45	78.60	11.34	15.38	<0.001
	H	93.17	11.32	91.63	11.24	12.93	<0.001

Notes: WHR – waist-hip ratio, L – lower, H – higher, *NS* – no significant difference.

Highly significant changes were noted in all analyzed parameters, excluding HR in men who used the sauna rarely (Table 9). A significant increase in HR values (by 9.6 bpm, $p < 0.006$) was observed in frequent sauna bathers. Frequent sauna users were also characterized by a greater decrease in the measured values of SBP (by 11.36 mmHg), DBP (by 7.78 mmHg) and body mass (by 1.5 kg).

Table 9. Descriptive statistics of physiological parameters in participants who used the sauna rarely (N = 16) and often (N = 14), before and after sauna treatment

Variable	FQS	Before sauna		After sauna		Difference	
		mean	*SD*	mean	*SD*	*t*	*p*
SBP, mmHg	R	136.94	11.01	128.69	11.89	4.54	<0.001
	O	132.00	14.84	120.64	11.09	4.82	<0.001
DBP, mmHg	R	81.31	12.47	75.13	8.37	2.63	0.019
	O	74.64	10.90	66.86	9.61	5.10	<0.001
HR, bpm	R	81.63	11.50	87.19	10.48	–1.62	*NS*
	O	66.50	9.61	76.07	14.64	–3.26	0.006
Body mass, kg	R	91.37	10.96	89.88	10.88	15.36	<0.001
	O	81.20	13.42	79.68	13.27	12.62	<0.001

Notes: FQS – frequency, R – rarely, O – often, *NS* – no significant difference.

Discussion

The aim of this study was to evaluate the effect of 72-ME of Finnish sauna bathing (four 12-minute sessions in a Finnish sauna, with 6-minute breaks in between sessions, including 1 minute of cold water immersion) on the body mass, HR and BP (SBP and DBP) in 30 adult men who were regular sauna users. Our findings seem to confirm the results of other studies demonstrating that the duration of exposure to high temperature play the key role in body mass reduction among sauna users. For example, Podstawski et al. (2014) examined 685 young women and men who attended two 10-minute sauna sessions (temperature: 90°C, humidity: approx. 35%) with a 5-minute cooling break in between. The average body mass loss was 0.30 kg, and the sauna-induced change in body mass was not significant. Similar results were reported by Boraczyński, Boraczyński, Podstawski, Borysławski, Jankowski (2018), where the average body mass loss determined in 230 young men after two 10-minute sauna sessions (temperature: 95°C, humidity, 25–27%) reached 0.49 kg and was not significant. In the present study, sauna exposure was more than twice longer, which could explain the significant reduction in body mass (by 0.8–1.3 kg). In another study, 6 young women and 6 young men with high PA levels attended three 20-minute Finnish sauna sessions (temperature: 70°C, humidity: approx. 17%) (Gutierrez, Mesa, Ruiz, Chirosa, Castillo, 2003). The average body mass loss was also significant (1.4 kg in men, 0.8 kg in women), but no significant changes were reported in body fat percentage. A significant decrease in body mass was noted in 10 young sedentary men who participated in three 15-minute sauna sessions (temperature: 90°C, humidity: 26%) with two cooling breaks in between (Pilch, Szygula, Zychowska, Gawinek, 2003). In another experiment, three 12-minute sauna sessions (temperature: 115°C, humidity: 35%) held on the same day induced a significant decrease in the body mass and BMI of young men with high PA levels (Prystupa, Rzepka, Lara, 2010). The abovementioned phenomena may be explained by the fact that during hot sauna bath the sweat is secreted at a rate of 0.6 to 1.0 kg per hour (Heinonen, Laukkanen, 2018). As the participants of described studies did not drink any fluids during experiment, the body mass loss was substantial.

A review of the literature suggests that the duration of sauna bathing combined with the duration of breaks in between sessions influence cardiovascular function. In a study by Cernych, Satas, Brazaitis (2018), the HR of 18 young men who attended a sauna over a combined period of 45 minutes (one 15-minute session and three 10-minute sessions at a temperature of 90°C, humidity of 20%, with 15-minute breaks in between the sessions) increased significantly from 65.6 bpm to 151 bpm. In the current study, the average HR did not exceed 90 bpm despite a similar overall time of exposure to high temperature. These variations could be attributed to differences in environmental conditions during the breaks in between sauna sessions. In the work of Cernych et al., the participants remained in a room with a temperature of 23°C during the break, whereas in this study, men spent the 6-minute break in a room with a temperature of 18°C and entered a cold water pool (11°C). Similar conclusions can be drawn from a study of 12 healthy men aged 60 years who attended two 10-minute sauna sessions (temperature: 80°C, humidity: 35%) with 20-minute breaks ending with cold water immersion (Radtke et al., 2016). In the cited study, SBP and DBP values also decreased during sauna, but SBP values clearly increased after cold water immersion. In contrast, Podstawski, Borysławski, Clark, Laukkanen, Gronek (2020) reported decrease in SBP and DBP values in 55 young men after a single 16-minute sauna session regardless of cooling mode (immersion in a pool or cold shower). In another experiment, 19 middle-aged women and men attended a single 25-minute session in a sauna (temperature: 95°C, humidity: 13–20%) (Ketelhut, Ketelhut, 2019). Their average HR increased from 64 bpm to 116 bpm immediately after sauna, but it decreased to 87 bpm already five minutes after the treatment. The participants remained in a room with a temperature of 25°C after the sauna without whole body cooling. In the cited experiment, sauna bathing exerted a different effect on BP values than that noted in present study. Average SBP increased from 120 mmHg to 135 mmHg, and reached 118 mmHg on average in the fifth minute after sauna. In turn, DBP increased from 82 mmHg to 90 mmHg, but dropped to 73 mmHg after 5 minutes in a room with a temperature of 25°C. A single, shorter stay in a sauna appears to exert a different effect on cardiovascular function. A significant increase in HR values (59.3 bpm vs 65.0 bpm) and a non-significant increase in BP values (127.9/78.9 mmHg vs 127.6/79.3) were reported in nine young men after a single 15-minute session in a sauna (temperature: 100°C, humidity: 30–40%) (Zalewski et al., 2014). In the present study, completely different changes were observed in HR and BP values, which could be attributed to differences in anthropometric parameters as well as differences in the duration of sauna bathing. In this study, considerable differences in SBP and DBP values were observed after four 12-minute sauna sessions regardless of the frequency of sauna use before the experiment. In a study analyzing 16 young men who attended two 8-minute sauna sessions (temperature: 90°C, humidity: 50–60%) with a 2-minute break in a cold shower and a 10-minute passive rest period outside the sauna, only a significant decrease in SBP values was reported during the first 8-minute sauna session (Gayda et al., 2012). The participants had not regularly used the sauna before the experiment, which suggests that cardiovascular function is more likely to be influenced by the number of sauna sessions during a single treatment, rather than previous sauna experience. Laukkanen et al. (2019) also reported a significant increase in the HR values of 93 middle-aged women and men who participated in a single sauna session (temperature: 75°C, humidity: 10–20%) with longer exposure to thermal stress (two 15-minute sessions with a 2-minute break in a warm shower). However, the results reported by Zaccardi, Laukkanen, Willeit, Kunutsor, Kauhanen, Laukkanen, (2017) in a group of 1621 men aged 40–60 years reveal a clear correlation between the frequency of sauna bathing and the risk of cardiovascular diseases. According to the authors, regular and frequent sauna use improves endothelial function in individuals with a risk of cardiovascular disease, whereas intermittent body warming and cooling stimulates the autonomic nervous system and, consequently, lowers blood pressure. For this reason, regular sauna bathers should be less exposed to the risk of cardiovascular disease than infrequent sauna goers and persons with a short history of sauna use. Similarly to the results reported by Zaccardi et al. (2017), our findings suggest that regular and frequent sauna bathing improves cardiovascular function. In this study, resting HR and BP values were lower in frequent sauna users than in men who had rarely visited the sauna before the experiment (HR: 66 bpm vs 81 bpm; BP: 132/74 mmHg vs 136/81 mmHg).

Strengths and Limitations

This paper makes a novel contribution to the literature by providing information about the influence of thermal stress on healthy men. The authors are aware of some limitations of the current study. Firstly, the control group was not created. We have reviewed many studies concerning sauna bathing and only a few of them involved the controls for comparisons. In the present study, multiple factors were analyzed in the context of sauna bathing, therefore the inclusion criteria for the control group would be ambiguous. Secondly, only the results of male participants were presented in our study. We invited healthy women to participate in the experiment, but the response rate was very low. Therefore, female participants were not included in this study. On the other hand, the findings of Kirby, Lucas, Cable, Armstrong, Weaver, Lucas (2021) suggest that the physiological effects of sauna bathing are similar in both physically active women and men. We conducted a multifactorial assessment of the effects of sauna bathing in a group of male participants, which is one of the strengths of this study. Nevertheless, studies involving a greater number of participants of both sexes could provide a basis for comparison with our findings.

Conclusions

The results of the present study generally confirm previous observations regarding the influence of thermal stress on cardiovascular function. Blood pressure decreased after sauna regardless of the participants' body mass, age and PA levels. Heart rate values increased in all studied subjects, but a greater increase was noted in younger and slimmer men who were frequent sauna users and were more physically active. Sauna induced a significant decrease in body mass regardless of the participants' age, PA level and body composition. The observed cardiovascular responses were induced by intermittent exposure to extreme thermal conditions: high air temperature in the sauna, followed by low water temperature in the paddling pool. Therefore, repeated 12-minute sessions in a Finnish sauna can be recommended for healthy men with average and high PA levels as a treatment that enhances cardiovascular function and promotes body mass loss.

References

Blum, N., Blum, A. (2007). Beneficial effects of sauna bathing for heart failure patients. *Experimental and Clinical Cardiology, 12* (1), 29–32.

Boraczyński, T., Boraczyński, M., Podstawski, R., Borysławski, K., Jankowski, K. (2018). Body mass loss in dry sauna and heart rate response to heat stress. *Revista Brasileria de Medicina do Esporte*, *24* (4), 258–262. DOI: 10.1590/1517-869220182404172175.

Borysławski, K., Szaliłow, K., Bielec, G., Omelan, A., Podstawski, R. (2021) The human body's response to the conditions in the sauna. *Physical Activity Review*, *9* (2), 11–17. DOI: 10.16926/par.2021.09.17.

Cernych, M., Satas, A., Brazaitis, M. (2018). Post-sauna recovery enhances brain neural network relaxation and improves cognitive economy in oddball tasks. *International Journal of Hyperthermia*, *35* (1), 375-382. DOI: 10.1080/02656736.2018.1504992.

Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.A., Pratt, M., Ekeleund, U., Yngve, A., Sallis, J.F., Oja, P. (2003). International Physical Activity Questionnaire: 12-Country Reliability and Validity. *Medicine & Science in Sports & Exercise*, *35* (8), 1381–1395. DOI: 10.1249/01.MSS.0000078924.61453.FB.

Crandall, C.G., Wilson, T.E., Marving, J., Vogelsang, T.W., Kjaer, A., Hesse, B., Secher, NH. (2008). Effects of passive heating on central blood volume and ventricular dimensions in humans. *Journal of Physiology*, *586*, 293–301. DOI: 10.1113/jphysiol.2007.143057.

Crinnion, W.J. (2011). Sauna as a valuable clinical tool for cardiovascular, autoimmune, toxicant-induced and other chronic health problems. *Alternative Medicine Review*, *16* (3), 215–225.

Gayda, M., Paillard, M., Sosner, P., Juneau, M., Garzon, M., Gonzalez, M., Belanger, M., Nigam, A. (2012). Effects of sauna alone and postexercise sauna baths on blood pressure and hemodynamic variables in patients with untreated hypertension. *Journal of Clinical Hypertension*, *14*, 553–560. DOI: 10.1111/j.1751-7176.2012.00637.x.

Gibson, A.L., Holmes, J.C., Desautels, R.L., Edmonds, L.B., Nuudi, L. (2008). Ability of new octapolar bioimpedance spectroscopy analyzers to predict 4-component-model percentage body fat in Hispanic, black, and white adults. *American Journal of Clinical Nutrition*, *87* (2), 332–338.

Gryka, D., Pilch, W., Szarek M., Szyguła Z, Tota Ł. (2014). The effect of sauna bathing on lipid profile in young, physically active, young males. International Journal of Occupational Medicine and Environmental Health, *27* (4), 608–618. DOI: 10.2478/s13382-014-0281-9.

Gutierrez, A., Mesa, J.L.M., Ruiz, J.R., Chirosa, L.J., Castillo, M.J. (2003). Sauna-induced rapid weight loss decreases explosive power in women but not in men. *Int J Sports Med.*, *24*, 518–522.

Hannuksela, M., Ellahham, S. (2001). Benefits and risks of sauna bathing. *American Journal of Medicine*, *110* (2), 118–126.

Heinonen, I., Laukkanen, J.A. (2018). Effects of heat and cold on health, with special reference to Finnish sauna bathing. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *314*, R629–R638. DOI: 10.1152/ajpregu.00115.2017.

Hussain, J.N., Greaves, R.F., Cohen, M.M. (2019). A hot topic for health: results of the global sauna survey. *Complementary Therapies in Medicine*, *44*, 223–234. DOI: 10.1016/j.ctim.2019.03.012.

Ketelhut, S., Ketelhut, R.G. (2019). The blood pressure and heart rate during sauna bath correspond to cardiac responses during submaximal dynamic exercise. *Complementary Therapies in Medicine*, *44*, 218–222. DOI: 10.1016/j.ctim.2019.05.002.

Kirby, N.V., Lucas, S.J.E., Cable, T.G., Armstrong, O.J., Weaver, S.R., Lucas, R.A.I. (2021). Sex differences in adaptation to intermittent post-exercise sauna bathing in trained middle-distance runners. *Sports Medicine – Open*, *7*, 51. DOI: 10.1186/s40798-021-00342-6.

Kowatzki, D., Macholdt, C., Krull, K., Schmidt, D., Deufel, T., Elsner, P., Fluhr, J.W. (2008). Effect of regular sauna on epidermal barrier function and stratum corneum water-holding capacity in vivo in humans: a controlled study. *Dermatology*, *217* (2), 173–180. DOI: 10.1159/000137283.

Kukkonen-Harjula, K., Kauppinen, K. (2006). Health effects and risk of sauna bathing. *International Journal of Circumpolar Health*, *65* (3), 195–205.

Laukkanen, T., Khan, H., Zaccardi, F., Laukkanen, J.A. (2015). Association between sauna bathing and fatal cardiovascular and all-cause mortality events. *JAMA Internal Medicine*, *175* (4), 542–548. DOI: 10.1001/jamainternmed.2014.8187.

Laukkanen, T., Lipponen, J., Kunutsor, S.K., Zaccardi, F., Araujo, C., Makikallio, T.H., Khan, H., Willeit, P., Lee, E., Poikonen, S., Tarvainen, M., Laukannen, J.A. (2019). Recovery from sauna bathing favorably modulates cardiac autonomic nervous system. *Complementary Therapies in Medicine*, *45*, 190–197. DOI: 10.1016/j.ctim.2019.06.011.

Lee, P.H., Macfarlane, D.J., Lam, T.H., Stewart, S.M. (2011). Validity of the International Physical Activity Questionnaire Short Form (IPAQ-SF): a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *8*, 115. DOI: 10.1186/1479-5868-8-115.

Leung, P-C. (2017). Rehabilitation training in artificially heated environment. *Journal of Exercise Rehabilitation*, *13* (5), 546–549. DOI: 10.12965/jer.1734958.479.

Perasalo, J. (1988). Traditional use of the sauna for hygiene and health in Finland. *Annals of Clinical Research*, *20* (4), 220–223.

Pilch, W., Szygula, Z., Zychowska, M., Gawinek, M. (2003). The influence of body hydration on chosen physiological reactions to sauna training. *Journal of Human Kinetics*, *9*, 31–37.

Pippi, R., Bini, V., Reginato, E., Aiello, C., Fanelli, C. (2021) Are three months multidisciplinary lifestyle intervention enough to get benefits on blood pressure in overweight/obese adults? *Physical Activity Review*, *9* (1), 40–53. DOI: 10.16926/par.2021.09.06.

Podstawski, R., Boraczyński, T., Boraczyński, M., Choszcz, D., Mańkowski, S., Markowski, P. (2014). Sauna-induced body mass loss in young sedentary women and men. *Scientific World Journal*, 307421. DOI: 10.1155/2014/307421.

Podstawski, R., Borysławski, K., Clark, C.C.T., Laukkanen, J.A., Gronek, P. (2020). The effect of 16-minute thermal stress and 2-minute cold water immersion on the physiological parameters of young sedentary men. *Montenegrin Journal of Sports Science and Medicine*, *9* (1), 57–65. DOI: 10.26773/mjssm.200308.

Podstawski, R., Borysławski, K., Laukkanen, J.A., Clark, C.C.T., Choszcz, D. (2019). The effect of prolonged thermal stress on physiological parameters of young, sedentary men and the correlations with somatic features and body composition parameters. *HOMO Journal of Comparative Human Biology*, *70* (2), 119–128. DOI: 10.1127/homo/2019/1016.

Prystupa, T., Rzepka, A., Lara, W. (2010). Changes of selected physiological indices in men under the influence of thermal heating and cooling. [in Polish]. *Pedagogics, Psychology, Medical-Biological Problems of Training and Sports*, *1*, 162–168. Retrieved from: https://www.sportpedagogy.org.ua/html/journal/2010-01/html-en/10ptrthc.html.

Radtke, T., Poerschke, D., Wilhelm, M., Trachsel, L.D., Tschanz, H., Matter, F., Jauslin, D., Saner, H., Schmid, J-P. (2016). Accute effects of Finnish sauna and cold-water immersion on haemodynamic variables and autonomic nervous system activity in patients with heart failure. *European Journal of Preventive Cardiology*, *23* (6), 593–601. DOI: 10.1177/2047487315594506.

Zaccardi, F., Laukkanen, T., Willeit, P., Kunutsor, S.K., Kauhanen, J., Laukkanen, J.A. (2017). Sauna bathing and incident hypertension: a prospective cohort study. *American Journal of Hypertension*, *30* (11), 1120–1125. DOI: 10.1093/ajh/hpx102.

Zalewski, P., Zawadka-Kunikowska, M., Słomko, J., Szrajda, J., Klawe, J.J., Tafil-Klawe, J., Newton, J. (2014). Cardiovascular and thermal response to dry-sauna exposure in healthy subjects. *Physiology Journal*, *106049*. DOI: 10.1155/2014/106049.

Żychowska, M., Półrola, P., Chruściński, G., Zielińska, J., Góral-Półrola, J. (2017). Effects of sauna bathing on stress-related genes expression in athletes and non-athletes. *Annals of Agricultural and Environmental Medicine*, *24* (1), 104–107. DOI: 0.5604/112321966.1233977.

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