Journal of Physical Education and Sport ® (JPES), Vol.20 (3), Art 204, pp. 1481 - 1490, 2020
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

The physiological effects of sauna and rowing on former elite athletes with hypertension

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Published online: May 30, 2020
(Accepted for publication: May 18, 2020)
DOI:10.7752/jpes.2020.03204

Abstract
The effect of thermal stress, such as sauna, on the physiological parameters of older, overweight and physically active former athletes remains insufficiently investigated. The aim of the study was to determine the effect of sauna first and then the combined effects of sauna and physical training on physiological parameters in overweight former elite athletes with hypertension and high levels of physical activity. Ten middle-aged former athletes who were overweight but physically active attended the first 10-minute sauna intervention (temperature 90-91°C; humidity: 14-16%) and the second intervention combining 20-minute training on a rowing ergometer training and a 10-minute sauna session one week later. Morphological and body composition parameters were determined before the first session. Heart rate (HR) and blood pressure (BP) were measured before and after both training sessions. The participants were overweight (BMI – 27.83±0.7 kg/m^2, PBF – 22.65±4.6%) and had elevated lipid parameters (total cholesterol – 210.20±39.7 mg/dl; HDL – 40.00±7.9 mg/dL; LDL – 122.21±14.48 mg/dl; triglycerides – 200.00±96.07 mg/dl). The highest HR values were noted during rowing ergometer training (115.6±3.7 bpm), and the highest maximal values during sauna were observed after ergometer training (132.4±4.4 bpm). Two hours after sauna, BP values decreased to 142.3±2.7/91.7±2.7 mmHg, and a significant decrease to normal levels (135.6±3.9/84.3±3.5 mmHg) was observed after rowing ergometer training combined with sauna. In conclusion, 20-minute rowing ergometer training combined with a 10-minute sauna session significantly decreased blood pressure in former elite athletes. The lowest BP values were noted in the second hour of recovery.
Key words: Finnish sauna, rowing ergometer, physically active former athletes, physiological parameters, somatic features, body composition

Introduction

In regular sauna users, heart rate (HR) has been shown to increase to approximately 100-110 bpm (Sawicka, Brzostek, & Kowalski, 2007), whilst some reports suggest HR can rise to, in excess of, 140-150 bpm concomitant to a rise in ambient temperature (Podstawski et al., 2019; Tei et al., 1995). An even greater increase in HR is observed in persons who do not use the sauna ~~on~~ regularly, which can be attributed to an absence of prolonged adaptations to high temperature (Leppäluoto, Tuominen, Väänänen, Karpakka, &Vouri, 1986). In healthy adult women and men,an increase to approximately 120 bpm is considered a beneficial adaptive response, whereas 140 bpm or greater is excessive because it is associated with higher cardiac output accompanied by diastolic shortening (Sawicka et al., 2007). Higher core temperature and reflex stimulation of adrenergic cardiac beta-receptors is the likely mechanism of this increase in HR (Kukkonen-Harjula&Kauppinen, 2006). The rise in HR is also influenced by other factors, including the duration of stay in the sauna, age, gender and physical endurance. Recent research has revealed that HR values are influenced not only by somatic (height and body weight) and anthropometric parameters (body mass index - BMI, waist-to-hip ratio - WHR, body surface area - BSA) (Boraczyński, Boraczyński, Podstawski, Borysławski, Jankowski, 2018), but also by body composition parameters (percent body fat - PBF, body fat mass – BFM, visceral fat level – VFL), where HR generally increases with a rise in the above parameters during sauna use (Podstawski et al., 2019).

Sauna bathing appears to exert equivocal effects on BP, conceivably attributed to the applied method of measurement, type of sauna, duration of exposure, achievement of the “evaporation effect”, and heat acclimation in sauna users (Sawicka et al., 2007). In studies where electronic or manual sphygmomanometerswereused, sauna bathing delivered varied effects, including a minor increase (Leppäluoto, Arjamaa, Vuokinaho, &Ruskoaho, 1991), no change (Rismann, al.-Karawi, &Jorch, 2002) or a decrease in systolic blood pressure (SBP) (Kihara et al., 2002), a decrease in SBP and diastolic blood pressure (DBP) (Laukkanen, Laukkanen,

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&Kunustor, 2018; Laukkanen, Kunutsor, &Zaccardi, 2018) an increase in SBP accompanied by a decrease in DBP (Pilch et al., 2014), as well as an increase in both SBP and DBP (Ketelhut&Ketelhut, 2019; Podstawski et al., 2019). Frequent sauna bathing improves heat tolerance and decreases the magnitude of changes in BP (Hannuksela&Ellahham, 2001).

In comparison with conventional Finnish sauna (humidity: 10-20%), dry sauna with low humidity levels (5-10%) induces far greater hemodynamic changes, including a decrease in BP and vascular resistance (Kukkonen-Hariula, Oja, &Laustiola, 1989). When air humidity in the sauna cabin was increased by pouring water onto heated stones, a minor (3-15 mmHg) and transient rise in SBP was reported (Hasan & Karvonen, 1967). Immamura and Kihara demonstrated a mild, but statistically significant reduction in BP in patients with increased risk of cardiovascular disease who were subjected to regular infrared sauna baths for two weeks (Imamura et al., 2001; Kihara et al., 2002). Blood pressure may be difficult to stabilize within a consistent range when sauna users remain seated because temperature-induced peripheral vasodilation in the lower extremities and the absence of muscle pump activity compromise reflex compensatory vasoconstriction and reduce venous return (Sawicka et al., 2007; Vuori, 1988). In young sedentary and overweight men, prolonged thermal stress (4 x 10 minutes) in a sitting position induced a significant increase in the values of SBP and DBP which were positively correlated with anthropometric parameters (BM, BMI, BSA) and body composition parameters (PBF, BHM and VHL) (Podstawski et al., 2019).

The effect of thermal stress on physiological parameters in more homogeneous samples of participants remains insufficiently investigated. One such group is former elite athletes whose physical activity levels, diet and lifestyle habits change considerably after retirement (Stephan, Torregrosa, & Sanchez, 2007).These adverse changes place retired athletes at increased risk of lifestyle diseases, including overweight, obesity, cardiovascular diseases (e.g. hypertension) (Yao, Laurencelle, & Trudeau, 2018). Thus, the aim of this study was to determine the effects of sauna as well as sauna combined with physical training on physiological parameters in former elite athletes.

Materials and Methods

Participant Selection

The study was conducted in November 2019 on 10 former elite athletes (boxing – 1, judo – 1, soccer – 1, wrestling – 1, swimming – 2, Taekwondo – 2, volleyball – 2) aged 45-52 years (mean 47.80±2.57). All participants were former Polish, European and world champions, and several participants were Olympic medalists. The participants were informed about the purpose of the study during a special meeting at the University of Warmia and Mazury in Olsztyn (UWM). Ten athletes meeting the below inclusion criteria were recruited for the study. The subjects were characterized by high levels of physical activity (PA) and used the sauna regularly (at least once every two weeks). A baseline medical evaluation revealed that all participants were overweight and had mildly elevated blood pressure, but they were qualified by a physician to participate in the experiment.

Ethical approval

The study was approved by the Ethics Committee of the University of Warmia and Mazury in Olsztyn (UWM), Poland. All participants signed an informed consent form.

Instruments and procedures

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

Body height was measured to the nearest 0.1 mm with a stadiometer, and nude body mass was measured to the nearest 0.1 kg with a calibrated WB-150 medical scale (ZPU Tryb Wag, Poland) prior to the sauna session. Somatic features, including body mass (BM), body height (BH), body mass index (BMI), body surface area (BSA) and the waist-hip ratio (WHR), as well as body composition parameters, 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 were determined by bioelectrical impedance (Gibson, Holmes, Desautels, Edmonds, &Nuudi, 2008) with the InBody 720 body composition analyzer before the first sauna session.

In week I, all participants attended one 10-minute sauna session (temperature: 90°C; relative humidity: 14-16%) in a sitting position. Air temperature and humidity inside the sauna cabin and the neutral room, and the temperature of shower water were measured with the Voltcraft BL-20 TRH + FM-200 hygrometer and confirmed with the Stalgast 620711 laser thermometer. During exposure to high temperature in the sauna, physiological parameters, including heart rate ($HR_{min, avg, max}$), recovery time, peak training effect (PTE), energy expenditure, estimated oxygen uptake ($VO_{2\ avg, max}$), estimated excess post-exercise oxygen consumption ($EPOC_{avg, peak}$), estimated respiratory rate ($_{avg, max}$) and physical effort (easy, moderate, difficult, very difficult, maximal), were measured indirectly with Suunto Ambit3 Peak Sapphire heart rate monitors which are widely used in studies of the type (Podstawski et al., 2019). The HR monitors were placed on either wrist, and the sensorwas attached to the chest. Every pulsometer was calibrated to male sex, year of birth, body mass and PA level. The same pulsometers were used to assess training and weekly physical activity levels in the former athletes (Table 2). Heart rate and blood pressure (BP) were determined with an automatic digital blood pressure monitor (Omron M6 Comfort, Japan). The first measurement was performed by the participants at home on the morning preceding sauna. Subsequent measurements were conducted before the first session and immediately after each 10-minute sauna session during which the participants remained in a sitting position.

The measurements were carried out during 5-minute recovery breaks in a room with a temperature of 22°C and 40% relative humidity. After the measurements, the participants recovered by taking a 30-second cool shower set to a temperature of 14-15°C.In week II, the participants exercised on the Concept II rowing ergometer for 20 minutes. Ergometer training was followed by a 5-minute break during which HR and BP were measured. After the break, the participants attended a 10-minute sauna session conducted under nearly identical conditions to stage 1. The same procedure and equipment were used to measure HR and BP, including before and after rowing ergometer training. Physiological parameters were measured with HR monitors during training and sauna.

Statistical analysis

The measured data were processed statistically in the Statistica PL v. 10 application. The values of the asymmetry coefficient (As) were calculated to analyze the normality of distribution. The arithmetic means of the parameters measured after each of the four sauna sessions were compared by one-way (univariate) analysis of variance (ANOVA). The Least Significant Difference (LSD) post-hoc test was performed when the *F* value was statistically significant. The direction and strength of the relationships between interval features were determined by calculating Pearson's correlation coefficient (*r*).

Results

The distributions of all studied anthropometric features and body composition as well as physiological parameters did not deviate significantly from normal distribution (Table 1).

The subjects' average body mass (89.9 kg) was excessive relative to their height (179.6 cm), and their BMI values were within the overweight range (mean 27.8 kg/m^2). The values of WHR (0.91) were indicative of excess gynoid fat (WHR > 0.92), and the average VFL was high at 8.1 kg.

Table 1. Somatic and morphological parameters in former elite athletes

Parameter	Mean	SD	min-max	As
Age [years]	47.80	2.57	45-52	0.471
Body height [cm]	179.60	6.59	166-191	-0.506
Body mass [cm]	89.95	6.83	76.9-99.7	-0.581
TBW (Total Body Water) [L]	51.69	5.80	39.4-61.7	-0.543
Proteins [kg]	14.04	1.62	10.6-16.8	-0.569
Minerals [kg]	4.87	0.55	3.5-5.7	-1.368
BFM (Body Fat Mass) [kg]	19.35	4.00	11.4-24.3	-0.668
FFM (Fat-Free Mass) [kg]	70.60	7.94	53.6-84.2	-0.601
SMM (Skeletal Muscle Mass) [kg]	40.39	4.78	30.1-48.5	-0.637
BMI [kg/m^2]	27.83	0.71	26.5-29.0	-0.316
PBF (% Body Fat) [%]	22.65	4.56	13.6-30.3	-0.384
In Body Score	83.00	8.85	68.0-95.0	-0.112
Target Weight [kg]	82.89	9.31	63.0-99.0	-0.563
Weight Control [kg]	-7.06	4.60	-13.0-0.0	0.144
BFM Control [kg]	-7.06	4.60	-13.0-0.0	0.144
FFM Control [kg]	0.00	0.00	0.0-0.0	---
WHR	0.91	0.03	0.87-0.98	0.732
VFL (Visceral Fat Level) [kg]	8.10	1.52	5.0-10.0	-0.678
Leukocytes [10^3/µl]	6.28	0.67	5.28-7.18	-0.286
Erythrocytes [10^6/µL]	5.22	0.18	4.98-5.64	1.279
Hemoglobin [g/dL]	15.38	0.54	14.2-16.2	-0.879
Hematocrit [%]	44.51	1.95	41.0-48.4	0.350
Creatinine [mg/dL]	0.88	0.27	0.4-1.3	-0.387
Urea BUN [mg/dL]	5.75	1.47	3.9-8.2	0.223
Total cholesterol [mg/dL]	210.20	39.69	154.0-260.0	-0.110
HDL cholesterol [mg/dL]	40.00	7.95	31.0-57.0	1.092
LDL cholesterol [mg/dL]	122.21	14.48	101.1-140.0	-0.203
Triglycerides [mg/dL]	200.00	96.07	86.0-399.0	0.759
Sodium [mmol/L]	138.30	7.07	123.0-145.0	-1.437
Potassium [mmol/L]	4.35	0.44	3.59-5.00	-0.052
Blood sugar [mg/dL]	96.20	4.76	89.0-104.0	-0.089

Parameters such as weight control and BFM control indicate that the participants should lose around 7 kg of fat tissue (without FFM control) to achieve the target weight of 82.9 kg. The subjects were characterized by relatively high SMM (mean SMM of 40.4 kg), which can be attributed to their athletic performance in the past and high PA levels. The blood analysis revealed high erythrocyte levels (mean 5.2 10^6/µl). Total cholesterol (mean 210 mg/dL), triglyceride (mean 200 mg/dL) and HDL (mean 40mg/dL) values were within the moderate risk range, and LDL values (mean 122 mg/dL) were below the norm. The above results point to a higher risk of cardiovascular diseases. Blood sugar levels were within the norm (mean 86.2 mg/dL) (Table 1).

Table 2. Physical parameters associated with weekly physical activity (PA) levels in retired athletes (average values)

Parameter	Weekly PA level		
	Mean	SD	min-max
HR min [bpm]	82.99	4.05	75.3-90.0
HR avg [bpm]	118.69	3.67	113.8-125.6
HR max [bpm]	145.35	5.79	137.3-154.6
Energy expenditure per training [kcal]	474.3	213.2	94-818
Weekly energy expenditure [kcal]	3557.40	367.85	3033-4284
VO_{2avg} [mL/kg/min]	19.60	1.47	17.7-22.4
VO_{2max} [mL/kg/min]	29.18	1.37	26.8-31.4
$EPOC_{avg}$[mL/kg]	19.14	4.32	14.3-28.3
$EPOC_{max}$[mL/kg]	28.68	4.25	21.9-35.6
Respiratory rate $(RR)_{avg}$ [brpm]	22.09	1.51	21.1-26.1
Respiratory rate $(RR)_{max}$ [brpm]	30.59	1.66	28.7-33.3
Exercise intensity [s]			
Easy <107 [bpm]	844.3	294.7	488.1-1288.4
Moderate 107-124 [bpm]	984.0	265.1	481.0-1389.5
Difficult 125-141 [bpm]	1156.1	413.0	647.1-2129.9
Very Difficult 142-159 [bpm]	279.9	150.0	80.6-484.6
Maximal ≥ 160 [bpm]	9.7	13.1	0.0-38.0
Total	3273.9	260.3	2802.4-3860.7

The average HR during weekly training was observed within the moderate effort range (118.7±3.7 bpm), and the highest average HR was noted within the very difficult range (145.3 bpm). The participants burnt 474.3±213.2 kcal on average during one training session, and the average energy expenditure during weekly training reached 3557.4±368.8 kcal, which points to high PA levels. Average oxygen uptake (VO_{2avg}) during training was determined at 19.6±1.5 mL/kg/min, and VO_{2max} reached 29.2±1.4 mL/kg/min during maximal effort. During the process of restoring homeostasis after strenuous activity, the average and maximum values of excess post-exercise oxygen consumption (EPOC) were determined at $EPOC_{avg}$= 19.14±4.32 mL/kg and $EPOC_{peak}$= 28.68±4.25 mL/kg, respectively. The average respiratory rate (RR_{avg}) was 22.1±1.0, and RR_{max} was determined at 39.6±1.7 breaths/min. Total weekly training time was 3273.93±260.26 s. During training, the participants remained in the difficult effort range (125-141 bpm) for the longest time (1156.1±413.0 s), followed by the moderate and easy effort range (984.0±256.1 s and 844.2±294.7 s, respectively), whereas the duration of the maximal effort range was negligent (9.7±13.0 s) (Table 2).

During the 10-minute stay in the sauna, HR_{avg} was 88.0±3.9 bpm and HR_{max} was 103.4±5.9 bpm (easy effort range), and both parameters were significantly (p<0.01) lower than during 20-minute rowing ergometer training (115.6±3.7 and 124.6±2.7 bpm, respectively) and during sauna preceded by 20-minute rowing ergometer training (113.7±1.5 and 132.4±4.4 bpm, respectively). Energy expenditure during the 10-minute sauna session was determined at 57.8±5.4 kcal, and it was significantly (p<0.01) higher during 20-minute rowing ergometer training (27-28 strokes/min, mean distance - 4354.3±67.9 m) and during the 10-minute sauna session after training (189.0±1.61kcal/20 min and 114±7.7kcal/10 min, respectively) (Table 3).

Table 3. Physiological parameters during sauna and rowing ergometer sessions

Parameter		10-min sauna – week I			20-min ergometer – week II			10-min sauna – week II			*F*	*p*
		Mean	SD	min-max	Mean	SD	min-max	Mean	SD	min-max		
HR [bpm]	min	75.6	3.89	67-81	81.2	11.12	72-103	67.8	3.64	62-73	8.93	0.001
	avg	88.0	2.90	84-92	115.6	3.74	107-120	113.7	1.49	112-116	288.38	<0.001
	max	103.4	5.94	92-110	124.6	2.67	118-128	132.4	4.42	127-140	108.74	<0.001
Energy expenditure [kcal]		57.8	5.41	52-69	189.0	12.61	159-201	114.5	7.68	105-131	525.15	<0.001
VO_2 mL/kg/min]	avg	11.4	1.08	10-13	20.4	1.42	17-22	20.4	0.84	19-22	207.10	<0.001
	max	16.8	2.86	13-22	23.3	0.67	22-24	26.2	1.54	24-28	63.00	<0.001
EPOC [mL/kg]	avg	1.0	0.00	1-1	7.5	1.26	5-9	4.5	1.08	3-7	114.30	<0.001
	max	2.0	0.00	2-2	14.2	2.89	8-18	10.9	1.44	9-14	113.78	<0.001
Respiratory rate [brpm]	avg	15.5	0.85	15-17	22.7	1.76	18-25	19.5	0.85	18-21	85.49	<0.001
	max	21.7	1.16	20-24	26.7	1.33	23-28	25.2	1.48	24-29	37.19	<0.001
Effort range [s]												
Easy <107 [bpm]		590	15.5	556-600	101.4	155.37	27-541	141.0	76.81	61-290	72.93	<0.001
Moderate 107-124 [bpm]		10	15.5	0-44	1057.5	163.85	637-1173	453.0	115.38	269-635	205.38	<0.001
Difficult 125-141 [bpm]		-	-	-	41.1	69.28	0-226	125.8	55.57	24-189	15.65	<0.001
Total		600	0.0	600-600	1200.0	0.00	1200-1200	720.0	0.00	720-720		

The average and maximum values of VO_2 were also significantly lowest ($p<0.01$) during the 10-minute sauna session at 11.4±1.1 and 16.8±2.9 mL/kg/min, respectively, relative to the remaining forms of physical activity. The values of $VO_{2\ avg}$ and Vo_{2max} during 20-minute ergometer training (20.4±1.4 and 23.3±0.7 mL/kg/min, respectively) and 10-minute sauna after training (20.4±0.8 and 26.2±1.5 mL/kg/min, respectively) were identical ($p>0.05$). The value of $EPOC_{avg}$ was significantly ($p<0.001$) higher after training (7.5±1.3 mL/kg) than after the 10-minute sauna session preceded by rowing ergometer training (4.5±1.1 mL/kg) and after a 10-minute sauna session alone (1.0 mL/kg) in week I. The values of RR followed a similar trend, but maximum RR was significantly ($p<0.01$) higher during sauna preceded by training (RR_{max} – 29 breaths/min).

During the first 10-minute sauna session, the easy effort range (550±15.5 s) was significantly ($p<0.01$) longest, whereas the moderate effort range was longest during 20-minute rowing ergometer training (1057.5±163.85 s) and during the 10-minute sauna session after training (453.0±115.38 s). The moderate effort range was significantly ($p<0.01$) longer during 20-minute rowing ergometer training than during sauna in weeks I and II, whereas the difficult effort range was significantly ($p<0.01$) longer during sauna in week II (Table 3).

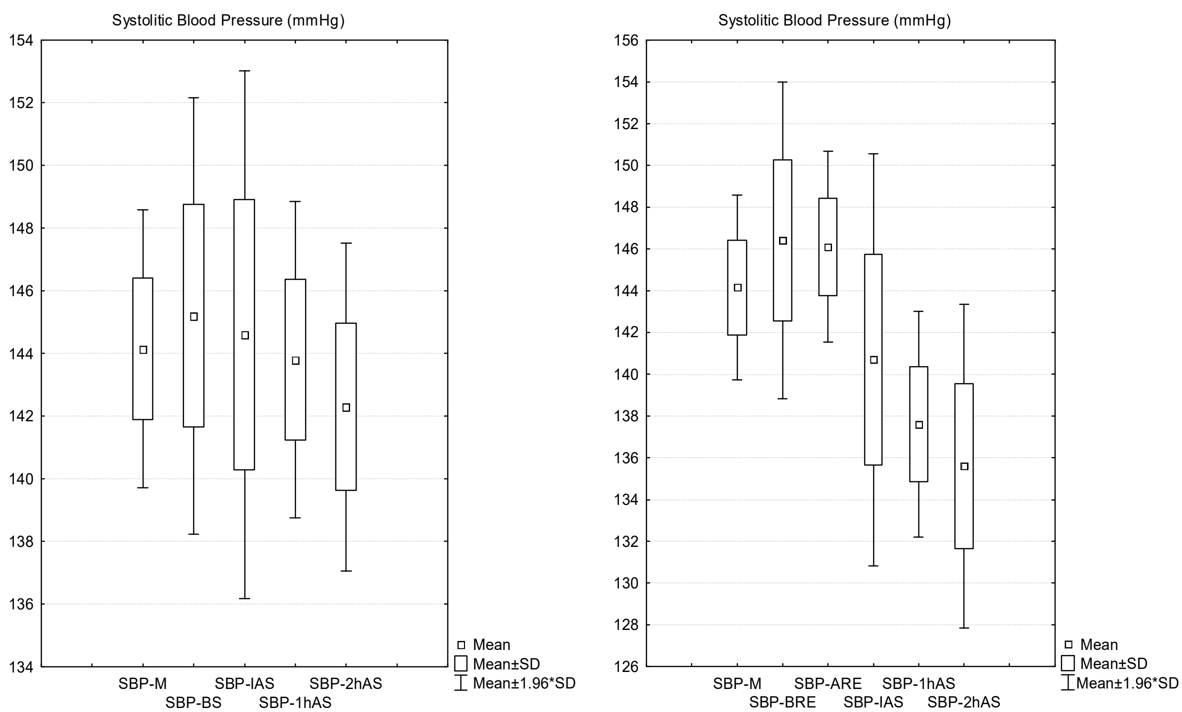

Fig. 1. Changes in SBP before, during and after physical effort in weeks I and II.

Notes: M- in the morning, BS- before sauna, IAS- immediately after sauna, 1hAS - one hour after sauna, 2hAS - two hours after sauna,BRE- before rowing ergometer training, ARE- after rowing ergometer training.

The morning values of SBP are indicative of mild hypertension (SBP_M = 144.4±2.3 mmHg). This parameter was somewhat higher before sauna (SBP_{BS} = 145.2±3.5 mmHg) and lower immediately after sauna (SBP_{IAS} = 144.6±4.3 mmHg). One hour after sauna, SBP decreased below morning levels (SBP_{1hAS} = 143.8±2.6 mmHg), and a further decrease was noted two hours after sauna (SBP_{2hAS} = 142.3±2.7 mmHg), but the noted values were still within the mild hypertensive range.

The profile of changes in SBP values was somewhat during in week II. The morning values of SBP were indicative of mild hypertension (and were identical to those measured in week I). Similar to week I, SBP was slightly higher before 20-minute rowing ergometer training (SBP_{BRE} = 146.4±3.9 mmHg), and a minor decrease was noted around 2 minutes after training (SBP_{ARE} = 146.1±2.3 mmHg). After the 10-minute sauna session in week II, SBP decreased to 140.7±5.0 mmHg, and a further decrease below hypertensive levels was noted one and two hours after sauna (SBP_{1hAS} = 137.6±2.7 and SBP_{2hAS} = 135.6±3.9 mmHg) (Fig. 1).

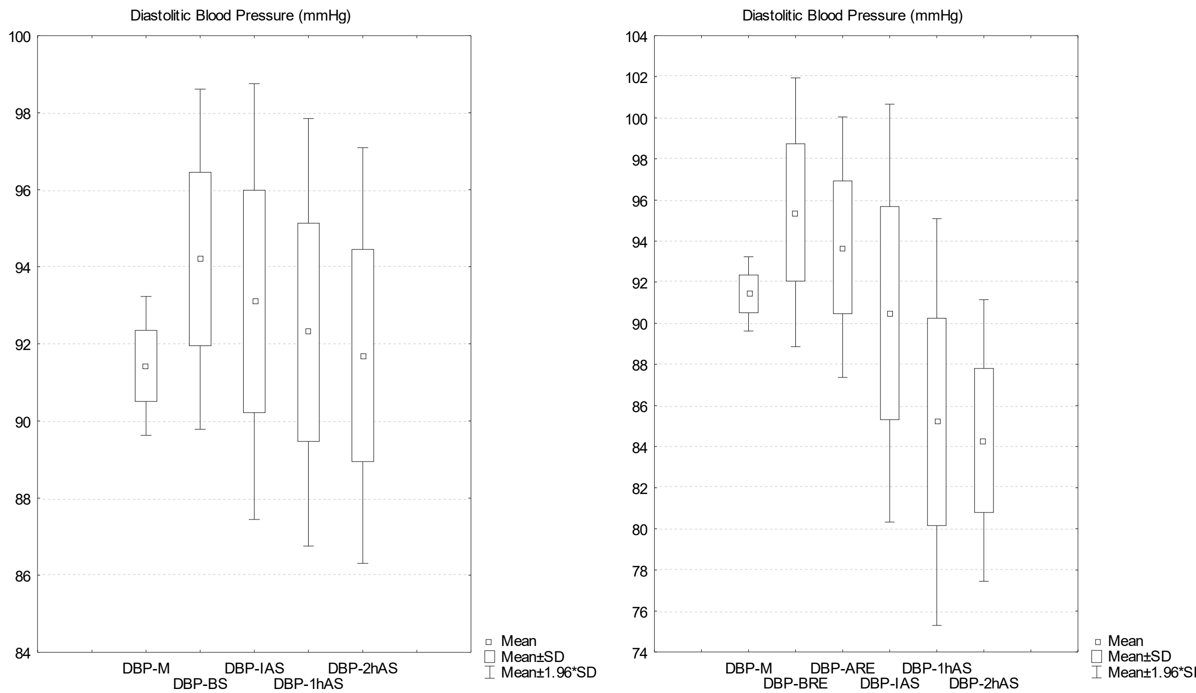

Fig. 2. Changes in DBP before, during and after physical effort in weeks I and II.
Notes:Refer to Fig. 1.

The morning values of DBP were also indicative of mild hypertension (DBP_M = 94.1±0.9 mmHg). This parameter was somewhat higher directly before sauna in week I (DBP_{BS} = 94.2±2.2 mmHg). A minor decrease in DBP was noted directly after sauna, but the measured value was higher than in the morning (DBP_{IAS} = 93.1±3.0 mmHg). After sauna, DBP continued to decrease until it fell below morning values (DBP_{1hAS} = 92.3±2.8 and DBP_{2hAS} = 91.7±2.7 mmHg).

In week II, DBP increased from mildly hypertensive levels (DBP_M = 94.1±0.9 mmHg) to DBP_{BRE} = 95.4±3.3 mmHg, and it decreased to pre-exercise levels after rowing ergometer training (DBP_{ARE} = 93.7±3.2 mmHg). After the 10-minute sauna session, DBP decreased below morning values (DBP_{IAS} = 90.5±5.2 mmHg) and continued to decrease two hours after sauna to reach normal levels (DBP_{1hAS} = 85.2±5.0 mmHg and DBP_{2hAS} = 84.3±3.5 mmHg) (Fig. 2).

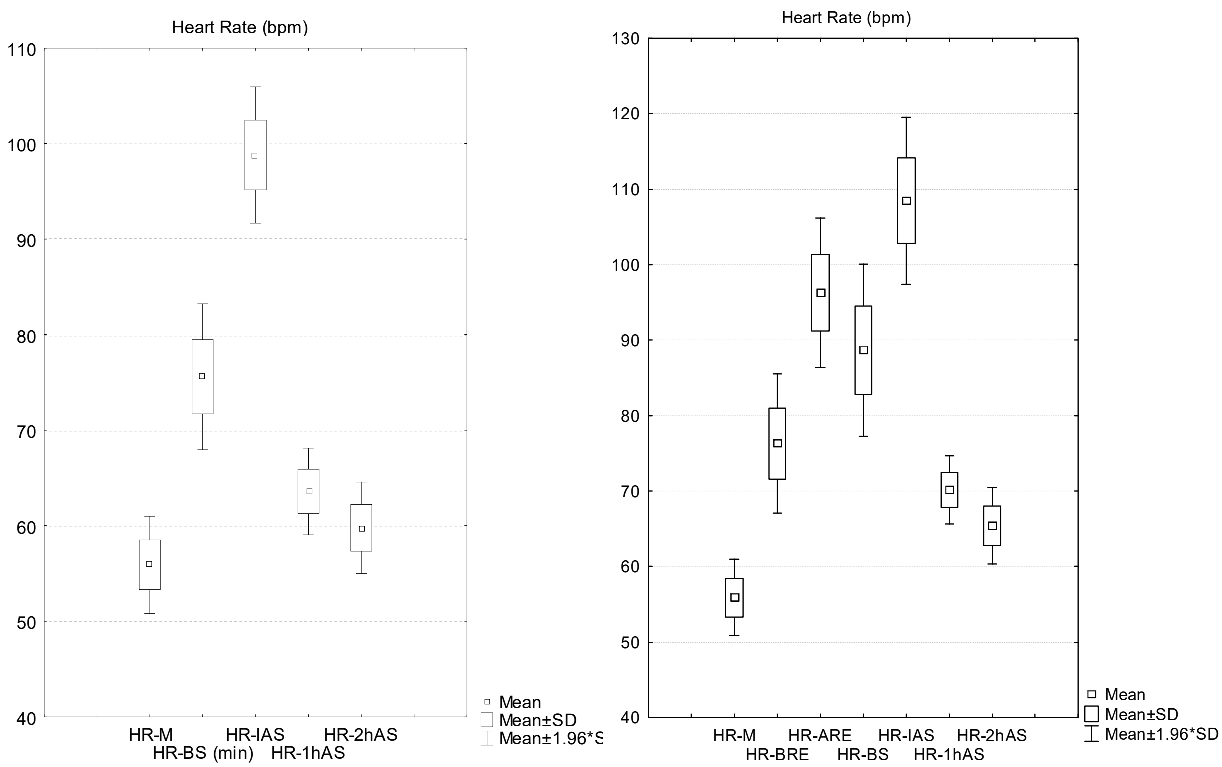

Fig. 3. Changes in HR before, during and after physical effort in weeks I and II.
Notes:Refer to Fig. 1.

Morning HR values (HR_M - 55.9±2.6 bpm) were relatively low and close to resting HR, which can be attributed to the participants' high PA levels. In week I, HR values before sauna were higher (HR_{BS} = 75.6±3.9 bpm), and they peaked after the 10-minute sauna session (HR_{IAS} = 98.8±3.6 bpm). HR values continued to decrease after sauna to reach resting HR values after two hours (HR_{1hAS} = 63.6±2.3 and HR_{2hAS} = 59.8±2.4 bpm). In week II, morning HR increased from resting values to HR_{BRE} = 76.3±4.7 bpm before 20-minute rowing ergometer training. The average HR during training was determined at HR_{ARE} = 96.3±5.0 bpm. During the first two minutes of the 5-minute break, HR decreased to HR_{BS} = 88.7±5.8 bpm. The average HR after the 10-minute sauna session was determined at HR_{IAS} = 108.5±5.7 bpm. One and two hours after sauna, the analyzed parameter decreased to HR_{1hAS} = 70.2±2.3 bpm and HR_{2hAS} = 65.4±2.7 (Fig. 3).

Discussion

The results of this study indicate that 10 minutes of exposure to thermal stressin a sauna has a greater impact on the human body when combined with exercise. The values of the analyzed physiological parameters (HR, energy expenditure, $VO_{2\ avg,\ max}$, $EPOC_{avg,\ peak}$ and $RR_{avg,\ max}$) in former elite athletes indicate that physiological processes are significantly intensified during rowing ergometer training combined with sauna. Thermal stress (temperature: 90°C; relative humidity: 14-16%) exerted similar effects on sedentary and overweight men who attended four 10-minute sauna sessions (Podstawski et al., 2019). In the cited study, the analyzed physiological parameters increased significantly during successive sauna sessions. Both experiments were performed on overweight men, but this study analyzed highly physically active former athletes who were regular sauna users, whereas the previous experiment involved sedentary males who used the sauna sporadically. In a study by Pilch et al. (2014), repeated exposure to thermal stress (three 15-minute sauna sessions with 5-minute breaks between sessions; temperature – around 91°C, humidity – 5-18%) induced a significant increase in HR from 66.6 to 126.0 bpm in sedentary men who were infrequent sauna users. Pilch, Żychowska, and Szyguła (2005) reported significant differences in the physiological parameters of 10 swimmers and 10 untrained students, where after three 15-minute sauna sessions (temperature: 92.3^{o}C, humidity: 27.4%) separated by 2-minute breaks, HR increased significantly (p=0.01) in both groups – by 61.8 bpm in swimmers and 62.7 bpm in untrained subjects (Pilch et al., 2005). A higher increase in HR in the untrained group points to a higher workload and higher metabolism economy in swimmers.Similar observations were made by Chorąży and Kwaśny (2005). Sutkowy, Woźniak, Boraczyński, Mila-Korzeniewska, &Boraczyński(2013) investigated the effects of sauna bathing on 43 young and healthy men aged 24.0±4.3 years who exercised on a cycle ergometer for 30 minutes and rested for 39 minutes in a sauna (temperature: 90^{o}C, humidity: 10%). They found that a single session in a Finnish sauna reduced the oxidative stress induced by 30 minutes of aerobic exercise.Red blood cell oxidative stress was determined based on the activity of superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx).

In the present study, 20 minutes of rowing ergometer training, followed by a 10-minute sauna session contributed to a significant decrease in BP (SBP and DBP) relative to a 10-minute sauna session alone. In week II, SBP and DBP values were within the norm after a 2-hour recovery period (135.6±3.94 and 84.3±349 mmHg, respectively) in athletes with initially elevated BP. In week I, DBP was within the norm, whereas SBP was somewhat below the morning value (but still within the mild hypertensive range) after a 2-hour recovery period. Similar results were reported by Laukkanen et al (2018). who investigated 102 subjects (mean age: 51.9±9.2 years, 56% male) with at least one cardiovascular risk factor. The participants were exposed to more severe thermal stress than in our study (30 minutes of sauna, temperature: 73°, humidity: 10-20%), but a significant decrease was noted in the average values of SBP (from 137 to 130 mmHg) and DBP (from 82 to 75 mmHg) post-sauna. Moreover, 30 minutes after recovery, SBP was below pre-sauna levels, which indicates that sauna bathing for 30 min has beneficial effects on arterial stiffness and BP. In this study, the participants were former athletes with mild hypertension who were highly physically active. The main aim of this study was to analyze changes in BP within two hours after physical effort and to evaluate the effect of sauna bathing combined with training on BP values. Sauna bathing could replace pharmacological therapy in the treatment of cardiovascular diseases such as hypertension. Pilch et al. (2014) studied ten healthy males aged 25-28 who did not participate in any sports and had used sauna baths only occasionally. After three sauna sessions of 15 minutes each with 5-min breaks between sessions (temperature: around 91^{o}C, humidity: 5-18%,), SBP increased significantly from 122.6 to 142.6 mmHg, and DBP decreased from 78.7 to 63.7 mmHg (Pilch et al., 2014). Similar results (an increase of 20 mmHg) were reported in earlier experiments where the average increase in SBP ranged from 15 to 25 mmHg (Prystupa, Wołyńska, &Ślężyński, 2009; Szyguła&Jurczak, 1993).

In healthy and physically active individuals, an increase in HR during physical effort is generally accompanied by an increase in BP as the force originating from the pumping action of the heart is exerted against the walls of blood vessels. During maximal effort, SBP increases to 200 mmHg, whereas DBP remains unchanged or is somewhat higher (DBP of 110 is the critical point at which exercise should be discontinued) (Jaskólski&Jaskólska, 2006). Trained individuals also respond differently to physical effort than untrained subjects (Ramos-Jiménez et al., 2008). The mechanisms of active vasodilation during whole body heating and cutaneous vasoconstriction during body cooling (through sweating) are more effective in trained individuals (Johnson, Minson, & Kellogg, 2014). In those subjects, short and moderate physical effort under supportive thermal conditions does not induce vasodilation (Smith & Johnson, 2016) which can occur during thermal stress conditions (Podstawski et al., 2016). During evaporation of sweat, fluid losses can occur from the blood plasma which, in combination with vasodilation, can decrease BP (Laukkanen et al., 2018). The above could explain why physical training combined with sauna induced such a profound decrease in BP. In former athletes with mild hypertension, higher but moderate values of HR were accompanied by lower BP. In week II, a significant decrease in BP values was observed despite an increase in HR induced by training and thermal stress. This observation paves the way to further research into the applicability of various forms of PA combined with sauna in the treatment of hypertension in variously-aged individuals. Training standardscombining the duration of exercise, exercise intensity, the optimal type of physical activity and sauna protocols should be developed to effectively control hypertension in different stages of the disease, with or without pharmaceutical treatment.

Conclusions

Based on our findings, physical training combined with sauna bathing can effectively lower blood pressure in former athletes with mild hypertension who maintain high physical activity levels. The combined training intervention significantly impacted the values of physiological parameters and induced greater decreases in blood pressure than the 10-minute sauna session alone. Systolic and diastolic blood pressurewas lowestat the end of the 2-hour recovery period during which these parameters were monitored.

Acknowledgements

The authors would like to thank all students who volunteered for the study.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This work was supported by the University of Warmia and Mazury in Olsztyn.

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