Effects of sauna after aerobic exercise on lipid profile, body composition, and muscle soreness in obese and non-obese men

Efectos de la sauna después del ejercicio aeróbico sobre el perfil lipídico, la composición corporal y el dolor muscular en hombres obesos y no obesos

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Abstract

Objective: This study aims to test the incremental effects of a single dry sauna session and infrared sauna exposure as recovery modalities after aerobic exercise on lipid profile, body composition, and muscle soreness in obese and non-obese men.
Methodology: Sixteen obese men (G1; age:20.25±1.24) and sixteen non-obese men (G2; age:20.75±0.93) participated in this study. Subjects were randomly assigned to receive all treatments (crossover design) with a 7-day measurement interval, including a dry sauna (DS, 40±2°C), an infrared sauna (IRS, 45±2°C), and sitting still (CTR, room temperature). Subjects performed aerobic exercise with an ergometer at a moderate intensity for 60 minutes. The parameters measured were lipid profile, body composition, and muscle soreness.
Results: There was a significant ($p<0.05$) decrease in HDL levels in G2 (IRS, CTR). Significant ($p<0.05$) increase in total cholesterol levels in G2 (IRS). Significant reduction in visceral fat level in G1 (DS, IRS, CTR) but not in G2. Significant increases in bone mass were observed in G1 (CTR) and G2 (DS). No significant differences in VAS values in all modalities.
Discussion: The addition of a recovery modality session failed to significantly change the lipid profile and body composition of subjects in both groups. Long-term chronic studies are needed to clarify the results. Based on the findings, we recommend the addition of IRS after exercise in obesity, based on the reduction in triglyceride and visceral fat levels. In the non-obese, passive recovery is the most effective.
Conclusions: Further research with longer interventions is needed to complement the findings.

Keywords

Dry sauna; infrared sauna; lipid profile; body composition; muscle soreness.

Resumen

Objetivo: El objetivo de este estudio es evaluar los efectos incrementales de una sola sesión de sauna seca y la exposición a la sauna infrarroja como modalidades de recuperación tras el ejercicio aeróbico en el perfil lipídico, la composición corporal y el dolor muscular en hombres obesos y no obesos.
Metodología: En este estudio participaron dieciséis hombres obesos (G1; edad:20,25±1,24) y dieciséis hombres no obesos (G2; edad:20,75±0,93). Los sujetos fueron asignados aleatoriamente para recibir todos los tratamientos (diseño cruzado) con un intervalo de medición de 7 días, incluyendo una sauna seca (SS, 40±2°C), una sauna de infrarrojos (SI, 45±2°C) y permanecer sentados en reposo (CTR, temperatura ambiente). Los sujetos realizaron ejercicio aeróbico con un ergómetro a intensidad moderada durante 60 minutos. Los parámetros medidos fueron el perfil lipídico, la composición corporal y el dolor muscular.
Resultados: Se observó una disminución significativa ($p<0,05$) en los niveles de HDL en G2 (SI, CTR). Aumento significativo ($p<0,05$) en los niveles de colesterol total en G2 (IRS). Reducción significativa del nivel de grasa visceral en G1 (SS, SI, CTR), pero no en G2. Se observaron aumentos significativos de la masa ósea en G1 (CTR) y G2 (SS). No se observaron diferencias significativas en los valores VAS en todas las modalidades.
Discusión: La incorporación de una sesión de modalidad de recuperación no logró cambiar significativamente el perfil lipídico y la composición corporal de los sujetos en ambos grupos. Se necesitan estudios crónicos a largo plazo para aclarar los resultados. Basándonos en los hallazgos, recomendamos la incorporación de SI después del ejercicio en casos de obesidad, debido a la reducción de los niveles de triglicéridos y grasa visceral. En personas no obesas, la recuperación pasiva es la más eficaz.
Conclusiones: Se necesitan más investigaciones con intervenciones más prolongadas para complementar los hallazgos.

Palabras clave

Sauna seca; sauna de infrarrojos; perfil lipídico; composición corporal; dolor muscular.

Introduction

Obesity is a global health issue with a steadily increasing prevalence. According to 2022 data, one in eight people worldwide is obese, with 2.5 billion adults (aged 18 and above) being overweight and 860 million of them obese (WHO, 2024). Obesity increases the risk of various diseases, including type 2 diabetes, cardiovascular disease, musculoskeletal disorders, and certain types of cancer (WHO, 2021; Zatońska et al., 2021). Prevention and treatment efforts are urgently needed, particularly lifestyle interventions such as physical activity. However, individual responses to these interventions often vary and are sometimes less than optimal (Swift et al., 2014). One promising alternative is the combination of exercise and additional therapies, such as sauna use. In this study, aerobic exercise and recovery modalities involving sauna exposure were applied with the aim of achieving multiple health benefits simultaneously. Specifically, this study investigates the incremental effects of a single session of dry sauna and infrared sauna exposure as recovery modalities after aerobic exercise on lipid profile, body composition, and muscle soreness in obese and non-obese men.

The physiological responses produced by regular sauna bathing are comparable to those induced by moderate- or high-intensity physical activity, such as walking (J. A. Laukkanen et al., 2018). Dry sauna exposure has been shown to reduce body mass and fat mass, and to lower the risk of cardiovascular disease (Gryka et al., 2014; J. A. Laukkanen et al., 2018; T. Laukkanen et al., 2018; Podstawski et al., 2014). In contrast, infrared saunas have not been extensively studied, and their effects on lipid profiles and body composition remain unclear. Nonetheless, infrared sauna therapy has been reported to relieve certain diseases and discomfort, reduce strength loss and muscle soreness, accelerate recovery, and attenuate declines in microvascular function (Kim et al., 2019; Kunutsor & Laukkanen, 2023; Rey et al., 2012; Sabapathy et al., 2021). Despite these benefits, sauna bathing cannot replace the more substantial health advantages of regular physical activity.

For obese individuals, physical activity is particularly essential to reduce weight by mobilizing the body's energy reserves, thereby lowering the risk of non-communicable diseases such as cardiovascular disease (Woudberg et al., 2018). Aerobic exercise of moderate intensity and long duration is especially effective, as it increases glycogen breakdown and lipid oxidation (Chycki et al., 2019; Houten & Wanders, 2010; Johnson et al., 2004). Fat oxidation is greater during moderate-intensity exercise compared to high-intensity exercise, partly due to increased fatty acid delivery to the working muscles (Horowitz & Klein, 2000; Muscella et al., 2020). Mobilization of fatty acids from fat stores is a key factor in reducing body weight through lowering body fat percentage (Mervanović, 2024).

Although the therapeutic benefits of sauna bathing have been studied extensively, research specifically addressing its role after exercise is still limited and yields conflicting results (Ahokas et al., 2023; Iwase et al., 2014; Kaharina et al., 2017; Mero et al., 2015; Podstawski et al., 2014, 2020; Wahjuni et al., 2019; Wiriawan, Kaharina, et al., 2024; Wiriawan, Setijono, et al., 2024). Further research is therefore warranted.

Previous studies comparing one infrared sauna session (IRS; 45±2°C; 20 min), traditional sauna (TRS; 40±2°C; 20 min), warm water immersion (WWI; 40±2°C; 20 min), and passive recovery (PAS) after submaximal aerobic exercise (60 min) found that WWI and IRS effectively reduced fatigue in both athletes and non-athletes, whereas PAS and TRS helped prevent muscle damage in non-athletes (Wiriawan, Kaharina, et al., 2024).

Additional evidence indicates that isotonic exercise during a steam sauna bath (40°C, humidity: 100%; 10 minutes) in healthy young men (n=6; age: 22±1 yr) reduced lactate levels and increased plasma free fatty acid levels, suggesting high fatigue and energy expenditure with relatively low perceived stress (Iwase et al., 2014). Rowing ergometer training (20 minutes) combined with a sauna session (90–91°C; humidity: 14–16%; 10 minutes) significantly reduced blood pressure in overweight former elite athletes with hypertension (age: 47.80±2.57; BMI: 27.83±0.7 kg/m^2) (Podstawski et al., 2020). Furthermore, countermovement jump (CMJ) results were significantly ($p<0.05$) higher (0.34 ± 0.09 m) after infrared sauna bathing post-endurance exercise compared to sitting without sauna bathing (0.32 ± 0.09 m) (Mero et al., 2015). Similarly, infrared sauna treatment (43±5°C; 20 minutes) following endurance training reduced declines in explosive performance and alleviated subjective muscle soreness in male basketball players (n=16; age: 18.9±2.3 yr) (Ahokas et al., 2023).

Although several studies have addressed the benefits of saunas, direct comparisons of dry saunas and infrared saunas after aerobic exercise, particularly in obese and non-obese men, remain scarce. Most prior research has examined sauna effects in isolation, without accounting for their interaction with aerobic exercise, or has been limited to a single population group. This study hypothesizes that both saunas and aerobic exercise independently influence lipid profile, body composition, and muscle soreness, but that physiological responses may differ between obese and non-obese individuals due to variations in body composition and metabolic characteristics. This study therefore seeks to provide new insights into differential physiological responses between the two groups and to present empirical evidence regarding the effectiveness of sauna use as an adjunct therapy for weight management and post-exercise recovery.

Method

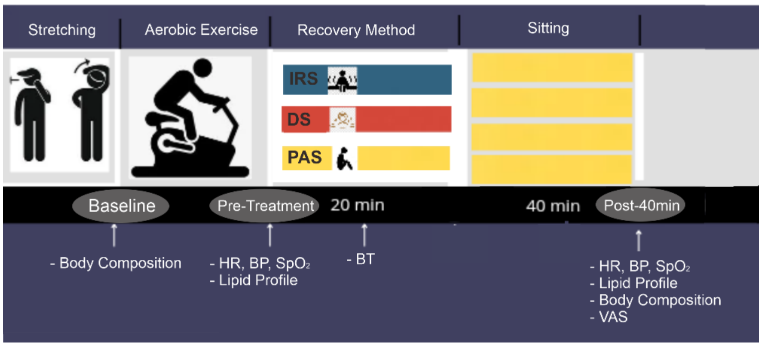
Participants

The study involved 16 obese subjects and 16 non-obese subjects aged 18–22 years, with regular resting pulses of 60–100 bpm. All participants were declared healthy by a physician and voluntarily agreed to participate in the study, as evidenced by signed informed consent forms. The obese group consisted of individuals with a BMI in the Asia-Pacific category of ≥25 kg/m^2 (WHO, 2000) and a waist circumference ≥90 cm. The non-obese group included individuals with a BMI in the Asia-Pacific category of 18.5–22.9 kg/m^2 (WHO, 2000) and a waist circumference <90 cm. Ethical approval for this study was obtained from the Health Research Ethics Committee of the Faculty of Public Health, Airlangga University (No. 178/EA/KEPK/2024).

Research Design

The research design and procedures were adapted from a previous study (Wiriawan, Setijono, et al., 2024). Subjects were randomized to receive all treatments (cross-over design) with a 7-day measurement interval, including dry sauna, infrared sauna, and sitting still. Participants were prohibited from consuming food 8 hours before measurement; only water was permitted, and fluid intake was controlled during the experimental trial. The use of nonsteroidal anti-inflammatory drugs and other recovery methods was prohibited before the measurement day. The research design is shown in Figure 1.

Figure 1. Schematic view of research design



Abbreviation: BMI=body mass index; HR=heart rate; BP=blood pressure; SpO2=peripheral oxygen saturation; BT=body temperature; VAS= visual analogue scale.

Participants performed stretching and aerobic exercise on an ergometer at light intensity (60–70% HRM) for 60 minutes. The parameters measured included body composition, heart rate (HR), blood pressure (BP), peripheral oxygen saturation (SpO_2), lipid profile, body temperature (BT), and muscle soreness. Body composition was measured before aerobic exercise (Baseline) and after 40 minutes of sitting still (Post-40 minutes). HR, BP, and SpO_2 were measured immediately after physical activity (Pre-treatment) and after 40 minutes of sitting still (Post-40 minutes). The lipid profile was assessed from blood samples collected immediately after physical activity (Pre-treatment) and after 40 minutes of sitting still (Post-40 minutes). BT was measured every 2 minutes during the recovery modality. After all measurements were completed, muscle soreness was assessed using a visual analogue scale.

Procedure

Aerobic Exercise Protocol

Subjects performed aerobic activity on an ergometer (TechnoGym Excite 700 Bike, TechnoGym, Rhode Island, USA) at a mild intensity of 60–70% HRM for 60 minutes. To prevent dehydration, participants were given mineral water at 20-minute intervals.

Recovery Session

All recovery modalities were administered at 7-day intervals, immediately after physical activity, for 20 minutes. The treatment conditions were as follows: IRS, 45 ± 2 °C (Orans infrared sauna room SN-96116I/65 °C/1.5 kW); TRS, 40 ± 2 °C (Smartmak dry sauna room SMT-041/65 °C/2.7 kW); and PAS, sitting at room temperature. Participants were provided with 200 ml of mineral water before and after each recovery modality to avoid dehydration.

Heart Rate, Blood Pressure, and Oxygen Saturation

Heart rate (Polar H10, Polar Electro Oy, Finland), blood pressure (Omron HEM-8712, Omron Manufacturing of Indonesia, Indonesia), and oxygen saturation (Beurer PO30, Germany) were measured immediately after physical activity (Pre-treatment) and after 40 minutes of sitting still (Post-40 minutes).

Lipid Profile

The lipid profile was measured from fingertip blood samples. The parameters assessed were triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and total cholesterol. Measurements were performed using a lipid profile analyser (LipidPro, Infopia Co., Ltd., South Korea) immediately after physical activity (Pre-treatment) and after 40 minutes of sitting still (Post-40 minutes).

Body composition

Body composition was assessed using a body composition scale (Tanita RD-545 InnerScan PRO, TANITA Corp. of America, USA). Parameters measured included body fat, visceral fat, total body water, muscle mass, basal metabolic rate (BMR), and bone mass. Measurements were taken before aerobic exercise (Baseline) and after 40 minutes of sitting still (Post-40 minutes).

Muscle Soreness

After all measurements, muscle soreness was assessed using a visual analogue scale (VAS) questionnaire (Klimek et al., 2017).

Body Temperature

Body temperature (Thermometer Beurer FT 65, Germany) was measured using a non-contact infrared thermometer on the forehead. Measurements were taken every 2 minutes during the recovery modality.

Data Analysis

Data were analysed using IBM SPSS Statistics 26 (IBM Corp., Armonk, NY, USA). Independent samples were analysed with the Mann–Whitney U test, and related samples with the Wilcoxon test. Results are presented as mean ± SD. Statistical significance was set at $p<0.05$. Changes from Baseline to Post-40 minutes and from Pre-treatment to Post-40 minutes were calculated as delta (Δ).

Results

Table 1 presents the characteristics of the subjects, with 16 obese and 16 non-obese participants included in the study. The results showed that BMI and waist circumference were significantly different between the two groups, which distinguished their characteristics.

Table 1. Subject Characteristics

Parameters	Obese Group (G1) n=16	Non-Obese Group (G2) n=16	p-value
Age (year)	20.25 ± 1.24	20.75 ± 0.93	0.192
Weight (kg)	80.30 ± 9.08	59.18 ± 4.37	0.003*
Height (cm)	170.16 ± 3.71	164.21 ± 4.69	0.001*
Body Mass Index (kg/m^2)	27.71 ± 2.69	21.94 ± 1.24	0.001*
Waist circumference (cm)	92.90 ± 4.11	77.99 ± 6.78	0.001*
Heart Rate rest (bpm)	83.06 ± 9.87	76.81 ± 11.33	0.220
Sistolic Blood Pressure (mmHg)	130.50 ± 9.10	121.69 ± 9.44	0.003*
Diastolic Blood Pressure (mmHg)	80.69 ± 5.46	74.43 ± 8.66	0.021*
Peripheral Oxygen Saturation/SpO_2 (%)	96.38 ± 1.31	94.88 ± 5.49	0.612
Body temperature (°C)	36.19 ± 0.37	36.14 ± 0.56	0.805

* Significant differences, p<0.05.

Table 2. Physiological Parameter Results

Parameter	Obese Group (G1) n=16			Non-Obese Group (G2) n=16		
	DS	IRS	CTR	DS	IRS	CTR
			Heart Rate (bpm)			
Pre-treatment	102.27 ± 10.16	97.33 ± 13.54	101.13 ± 15.52	95.63 ± 12.74	102.69 ± 12.17	96.06 ± 10.95
Post-40min	83.67 ± 8.80[A]	87.47 ± 11.89[a]	83.63 ± 12.15[A]	78.25 ± 12.32[A]	78.56 ± 13.03[A]	76.25 ± 11.64[A]
Δ	-18.60 ± 7.14	-9.87 ± 13.70	-17.50 ± 13.57	-17.53 ± 11.67	-24.13 ±8.92[B]	-19.81 ± 12.25
			Sistolic Blood Pressure (mmHg)			
Pre-treatment	132.13 ± 11.48	135.33 ± 13.54	132.44 ± 7.71	126.00 ± 11.28[b]	126.00 ± 11.34[b]	125.38 ± 11.22
Post-40min	129.07 ± 13.15	124.73 ± 11.31[a]	123.88 ± 7.33[A]	114.44 ± 10.99[AB]	116.47 ± 8.87[Ab]	118.38 ± 7.53
Δ	-3.07 ± 14.51	-10.60 ± 17.80[c]	-8.56 ± 8.33	-11.93 ± 13.59	-9.53 ± 12.63	-7.00 ± 13.04
			Diastolic Blood Pressure (mmHg)			
Pre-treatment	78.00 ± 6.88	83.00 ± 14.33	81.38 ± 8.23	73.44 ± 8.91	74.06 ± 9.64	77.25 ± 10.29
Post-40min	76.33 ± 6.99	78.93 ± 9.07	77.38 ± 9.34	69.81 ± 8.38[ab]	70.31 ± 8.59[b]	73.06 ± 9.58
Δ	-1.67 ± 9.08	-4.07 ± 12.86	-4.00 ± 10.87	-3.63 ± 8.22	2.69 ± 8.75	-4.19 ± 11.53
			Peripheral Oxygen Saturation/SpO_2 (%)			
Pre-treatment	96.73 ± 1.16	96.80 ± 0.77	97.38 ± 1.20	96.81 ± 0.91	97.00 ± 1.00	97.13 ± 1.09
Post-40min	96.87 ± 0.83	97.20 ± 0.94	97.19 ± 1.05	96.75 ± 1.06	97.00 ± 1.00	97.25 ± 1.18
Δ	0.13 ± 1.46	0.40 ± 1.12	-0.19 ± 1.87	-0.07 ± 1.07	0.00 ± 1.20	0.13 ± 1.71

[a] Indicates difference from pre p<0.05, [A] p<0.01; [b] Indicates difference from obese group p<0.05, [B] p<0.01; [c] Indicates difference from DS in obese group p<0.05.

Table 2 shows the results of the analysis of pulse rate, blood pressure, and oxygen saturation. All modalities significantly reduced HR after treatment in both groups (p<0.01). A significant decrease in SBP was found in G1 (IRS, CTR) and G2 (DS, IRS). A significant decrease in DBP was observed only in the G1 DS modality. Recovery performed for 60 minutes significantly reduced pulse rate.

Table 3. Lipid Profile Results

Parameter	Obese Group (G1) n=16			Non-Obese Group (G2) n=16		
	DS	IRS	CTR	DS	IRS	CTR
			Triglyceride (mg/dL)			
Pre-treatment	178.92 ± 95.27	160.10 ± 98.91	150.50 ± 82.16	119.90 ± 52.70	129.69 ± 71.23	137.73 ± 73.70
Post-40min	165.38 ± 61.01	135.91 ± 70.27	145.79 ± 65.82	125.80 ± 51.66	136.85 ± 43.82	111.67 ± 37.02
Δ	-13.54 ± 80.18	-25.10 ± 870.34	-4.71 ± 103.05	5.90 ± 43.03	7.15 ± 76.84	-26.07 ± 67.08
			HDL (mg/dL)			
Pre-treatment	42.45 ± 7.75	43.90 ± 6.23	44.00 ± 7.29	50.69 ± 11.27[b]	42.82 ± 7.59	44.31 ± 8.14
Post-40min	36.73 ± 7.50	37.80 ± 9.68	40.75 ± 10.95	47.62 ± 16.70[db]	36.27 ± 8.17[a]	36.69 ± 8.05[a]
Δ	-5.73 ± 9.92	-6.10 ± 10.55	-3.55 ± 10.86	-3.08 ± 16.13	-6.55 ± 11.79	-7.62 ± 12.42
			LDL (mg/dL)			
Pre-treatment	74.17 ± 25.23	58.60 ± 23.33	68.00 ± 12.33	98.29 ± 37.59	73.11 ± 12.58	62.08 ± 19.66[e]
Post-40min	80.00 ± 18.76	94.80 ± 29.58	77.00 ± 16.06	105.00 ± 34.07	90.22 ± 27.96	77.75 ± 21.79
Δ	-5.29 ± 40.75[c]	37.33 ± 32.18	9.00 ± 19.24	6.71 ± 52.14	17.11 ± 30.35	15.67 ± 31.00
			Total cholesterol (mg/dL)			
Pre-treatment	145.20 ± 29.98	144.00 ± 20.86	136.20 ± 24.14	153.83 ± 45.87	138.75 ± 22.05	137.40 ± 24.52
Post-40min	145.30 ± 24.11	151.00 ± 34.72	140.27 ± 30.38	154.33 ± 30.74	152.83 ± 29.59[a]	139.20 ± 24.74
Δ	0.10 ± 24.48	7.00 ± 33.42	4.07 ± 33.20	0.50 ± 40.59	14.08 ± 21.70	1.93 ± 18.94

[a] Indicates difference from pre p<0.05, [A] p<0.01; [b] Indicates difference from obese group p<0.05, [B] p<0.01; [c] Indicates difference from IRS in obese group p<0.05; [d] Indicates difference from IRS in non-obese group p<0.05; [e] Indicates difference from DS in non-obese group p<0.05.
Abbreviation: HDL= high-density lipoprotein; LDL = low-density lipoprotein.

Table 3 presents the results of lipid profile analysis, which showed no significant differences after modality administration. Total blood cholesterol levels tended to increase after treatment, but only the G2

IRS modality showed a significant increase. A similar trend was observed in HDL-cholesterol levels, which decreased after treatment, although only the G2 CTR modality showed a significant decrease. No significant differences were found in triglyceride and LDL-cholesterol levels. There was also no significant difference in the visual analogue scale (VAS) between modalities.

Table 4. Body Composition Results

Parameter	Obese Group (G1) n=16			Non-Obese Group (G2) n=16		
	DS	IRS	CTR	DS	IRS	CTR
Body fat (%)						
Baseline	23.53 ± 2.23	23.14 ± 1.84	24.03 ± 3.89	18.11 ± 4.66^{B}	17.13 ± 3.07^{B}	16.15 ± 2.92^{B}
Post-40min	28.07 ± 6.03	27.09 ± 6.61	31.31 ± 14.70	19.08 ± 5.75^{B}	20.57 ± 6.21^{b}	20.47 ± 6.63^{b}
Δ	4.54 ± 6.39	3.95 ± 6.26	7.2 ± 13.52	0.97 ± 6.01	3.44 ± 5.33	4.32 ± 5.98
Visceral fat (level)						
Baseline	9.47 ± 1.30	9.29 ± 0.99	9.67 ± 2.69	4.47 ± 1.88^{B}	4.38 ± 1.89^{B}	3.81 ± 1.76^{B}
Post-40min	8.07 ± 2.31^{a}	8.07 ± 1.86^{a}	8.20 ± 2.37^{a}	4.00 ± 1.69^{B}	4.06 ± 1.69^{B}	3.81 ± 1.56^{B}
Δ	-1.40 ± 1.55	-1.21 ± 1.72	-1.47 ± 1.85	-0.47 ± 0.99	-0.31 ± 0.87^{b}	0.00 ± 1.41^{b}
Total body water (%)						
Baseline	55.98 ± 1.64	56.28 ± 1.35	55.69 ± 2.76	59.96 ± 3.42^{B}	60.65 ± 2.25^{B}	61.38 ± 2.13^{B}
Post-40min	52.73 ± 4.33	53.45 ± 4.77	52.12 ± 7.01	59.11 ± 4.31^{B}	58.16 ± 4.53^{b}	58.24 ± 4.83^{b}
Δ	-3.99 ± 5.49	-2.83 ± 4.39	-3.51 ± 5.17	-0.80 ± 3.85	-2.49 ± 3.90	-2.64 ± 3.53
Muscle mass (kg)						
Baseline	55.97 ± 2.98	55.64 ± 2.57	56.31 ± 5.49	46.07 ± 3.67^{B}	46.46 ± 3.55^{B}	47.18 ± 3.63^{B}
Post-40min	51.98 ± 5.74	51.96 ± 6.31	51.78 ± 5.77	45.27 ± 3.23^{B}	44.31 ± 5.16^{B}	44.54 ± 4.95^{B}
Δ	-4.24 ± 5.61	-3.69 ± 5.49	-4.43 ± 5.91	-1.25 ± 4.38	-2.15 ± 3.16	-2.35 ± 3.95
BMR (kcal)						
Baseline	1731.40 ± 99.46	1719.57 ± 85.85	1742.93 ± 190.64	1411.93 ± 103.06^{B}	1415.06 ± 107.07^{B}	1437.13 ± 109.53^{B}
Post-40min	1663.33 ± 133.13	1653.71 ± 142.57	1676.53 ± 154.95	1401.13 ± 90.34^{B}	1384.81 ± 119.15^{B}	1398.44 ± 119.12^{B}
Δ	-68.07 ± 106.78	-65.86 ± 109.84	-66.4 ± 97.25	-10.80 ± 59.11	-30.25 ± 48.63	-38.69 ± 59.07
Bone mass (kg)						
Baseline	3.05 ± 0.17	3.04 ± 0.14	3.06 ± 0.29	2.55 ± 0.18^{B}	2.56 ± 0.17^{B}	2.60 ± 0.19^{B}
Post-40min	3.09 ± 0.20	2.96 ± 0.32	3.11 ± 0.32^{a}	2.59 ± 0.21^{aB}	2.55 ± 0.21^{B}	2.59 ± 0.19^{B}
Δ	0.04 ± 0.14	-0.09 ± 0.29	0.05 ± 0.07	0.04 ± 0.06^{c}	-0.01 ± 0.06^{B}	-0.01 ± 0.03^{db}

[a] Indicates difference from baseline p<0.05; [b] Indicates difference from obese group p<0.05, [B] p<0.01; [c] Indicates difference from IRS in non-obese group p<0.05; [d] Indicates difference from DS in non-obese group p<0.05.
Abbreviation: BMR = basal metabolic rate.

Table 4 shows the results of body composition measurements. No significant differences were observed in body fat, total body water, muscle mass, or BMR from baseline to post-40 minutes across modalities in both G1 and G2. A significant decrease in visceral fat was observed in G1 across all modalities, but similar results were not found in G2. This may be attributed to the 60 minutes of aerobic ergometer activity, which reduced visceral fat in obese subjects. A significant increase in bone mass was found in G1 (CTR) and G2 (DS), suggesting that DS may be more effective in increasing bone mass in non-obese subjects compared to other modalities.

Table 5. Muscle Soreness Results

	Obese Group (G1) n=16			Non-Obese Group (G2) n=16		
	DS	IRS	CTR	DS	IRS	CTR
Visual Analogue Scale (VAS)						
Post-40min	1.89 ± 1.54	2.18 ± 1.99	2.60 ± 1.90	1.91 ± 1.76	1.70 ± 1.42	2.40 ± 1.90

Table 5 presents the results of VAS data on muscle soreness, which showed no significant differences across modalities in either group.

Figure 2. Body temperature at DS administration

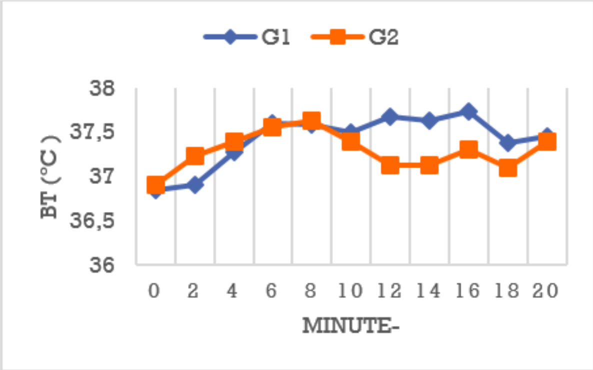


Figure 3. Body temperature at IRS administration

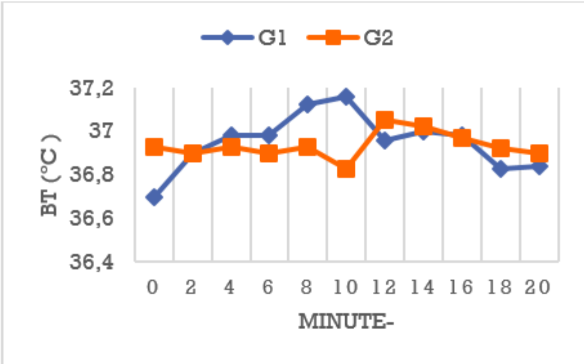
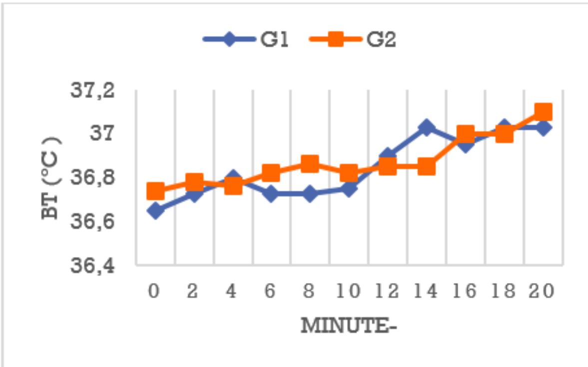


Figure 4. Body temperature at recovery sitting still (CTR)



Figures 2 to 4 illustrate body temperature fluctuations during recovery for each modality. The greatest increase occurred in the TRS modality. The body responded to heat exposure by raising core temperature to initiate thermoregulation.

Discussion

HR, SBP, DBP, SpO₂

There was a significant decrease in heart rate recovery (HRR) across all modalities in both G1 and G2. This indicates that physiologically, the human body can recover to its basal state after cessation of physical activity. The most significant decrease was observed in the G2 IRS modality (Δ = −24.13 ± 8.92), which differed significantly from G1. This suggests that IRS is more effective in reducing HR after aerobic exercise in the non-obese group compared to the obese group. Heart rate recovery after exercise is negatively correlated with BMI and waist circumference in obese young adults (Lourenço Dias et al., 2018). An increased waist–hip ratio, as an indicator of visceral adiposity, has been strongly associated with reduced cardiac parasympathetic and increased sympathetic activity in obese individuals (Araújo et al., 2016; Yadav et al., 2017). Parasympathetic reactivation is more efficient in individuals with normal BMI, whereas obese individuals exhibit decreased parasympathetic activity and increased sympathetic activity, resulting in slower HRR. This may explain the lower HRR in G1 compared to G2. Future studies may consider periodic pulse monitoring to complement these findings.

Systolic blood pressure tended to decrease after recovery modalities. Significant decreases were observed in G1 (IRS, p<0.05; CTR, p<0.01) and G2 (DS, p<0.01; IRS, p<0.01). DS appeared less effective in reducing systolic pressure in obese subjects. Systolic pressure in non-obese subjects differed significantly from that in obese subjects with DS and IRS administration, but not in the CTR modality. Similar trends were found for diastolic blood pressure, where significant differences were observed between DS and IRS in G1, and across all three modalities in G2. A decrease in diastolic pressure occurred across modalities, though only G2 DS showed a significant reduction. Previous studies have reported an increase in HR and BP during 25 minutes of sauna use, with levels rising periodically and then decreasing dramatically immediately after leaving the sauna room (Ketelhut & Ketelhut, 2019). However, blood pressure was not monitored during sauna use in the present study, which is a limitation. Therefore, this study cannot explain the precise effect of sauna exposure on blood pressure.

Oxygen saturation measurements showed no significant differences. The body has compensatory mechanisms that maintain oxygen saturation at relatively stable levels under normal conditions, regardless of body weight. In healthy subjects without chronic lung disease or severe respiratory disorders, oxygen saturation is maintained through mechanisms such as increased respiratory rate and efficient blood distribution (Podstawski et al., 2022; Yuniana, 2020).

VAS

The level of muscle soreness experienced after the administration of recovery modalities was assessed using VAS. VAS data were collected after all procedures were completed. The results showed no significant differences in VAS values across all modalities in both groups. Physiologically, the muscle recovery effects of post-aerobic exercise saunas were similar in both groups, consistent with previous studies suggesting that the body's response to heating and muscle recovery does not differ based on obesity status (Lee et al., 2012; Podstawski et al., 2022).

Lipid Profile

Triglycerides

Blood triglyceride levels decreased, although not significantly, after recovery in G1 (DS, IRS, CTR) and G2 (CTR). The most notable decrease in G1 occurred in the IRS modality, while in G2 it was found in CTR. Conversely, a slight increase in blood triglyceride levels was observed in G2 with DS and IRS modalities. It appears that the addition of DS and IRS modalities is more effective in reducing triglyceride levels in obese subjects compared to non-obese subjects. This is a positive finding for obese individuals, as a decrease in blood triglyceride levels after exercise indicates the use of triglycerides as an energy source (triglyceride lipolysis) (Muscella et al., 2020). Triglycerides are a storage form of fatty acids (FA), representing the most significant energy reserve in the body, approximately 60 times greater than the amount of energy stored as glycogen (Horowitz & Klein, 2000; Mervanović, 2024).

In people with diabetes, energy reserves accumulate in the form of glycogen in muscle and liver, as well as triglycerides in adipose tissue and muscle (Horowitz & Klein, 2000; Johnson et al., 2004; Mugabo et al., 2017). Physical activity stimulates the release of free fatty acids (derived from the breakdown of triglycerides) from fat tissue through lipolysis, and these fatty acids are subsequently used to produce energy (Ghosh & Collier, 2012; Muscella et al., 2020; Romero et al., 2022). Thus, body energy stores may be reduced, and in the long run, body fat levels may decrease. The body uses triglycerides stored in adipose tissue as fuel during aerobic exercise. When the body burns triglycerides as energy, blood triglyceride levels decline. This finding is consistent with previous studies, which reported reductions in plasma triglycerides following acute exercise (Lippi et al., 2019; Magkos et al., 2008; Santiago et al., 2020). Further research with longer intervention periods is needed to support these findings.

HDL

Blood HDL levels decreased after recovery in all groups, with significant reductions observed in G2 (IRS, p<0.05; CTR, p<0.05). Similar to triglycerides, HDL levels declined following aerobic exercise and the administration of recovery modalities. During exercise, fat oxidation as an energy source increases (Muscella et al., 2020). Long-chain fatty acids (LCFA) are absorbed in the duodenum and broken down into triglycerides, which form chylomicrons together with cholesterol and protein. These chylomicrons are transported into the bloodstream and delivered to muscle and fat cells for energy conversion (Miller, 1990). Triglycerides and plasma cholesterol are transported in four main classes of lipoproteins, one of which is HDL. HDL plays a key role in cholesterol transport (James et al., 2007; Slivkoff-Clark et al., 2012). The greater the fat oxidation, the more HDL is metabolized, which may explain the decrease in blood HDL levels after recovery. However, this effect may be temporary post-exercise, as HDL levels typically increase with regular exercise, yielding positive health benefits, including reduced cardiovascular risk (Argani et al., 2014; Kodama, 2007; Kühnast et al., 2015; Woudberg et al., 2018).

LDL

LDL levels showed no significant differences between pre- and post-measurements (p>0.05). Increases were observed across all modalities except in the G1 DS modality, which demonstrated a decrease. The administration of DS modality after aerobic exercise effectively reduced LDL levels in obese subjects. Thus, the addition of DS following exercise is recommended for obese individuals.

Regular, long-term exercise has been shown to reduce LDL levels. For instance, LDL levels decreased significantly after participants underwent intensive aerobic training combined with moderate-intensity resistance training (50% VO2max + total body resistance exercise [TRX]) for six weeks (Oh & Lee, 2023). Based on the present findings, the addition of DS after physical activity in obese individuals may optimize long-term LDL reduction. Nonetheless, further research involving long-term DS administration is required to confirm these results.

Total cholesterol

Total cholesterol levels increased after recovery in all groups, with a significant increase observed in G2 IRS modality (p<0.05). This result may reflect a temporary effect of the exercise performed. During recovery after exercise, the fat mobilization process remains active, lasting several hours to days depending on exercise duration and intensity (Horowitz & Klein, 2000; Lundsgaard et al., 2020).

In the long term, exercise provides positive benefits for both obese and non-obese individuals. Prolonged aerobic and/or resistance training reduces total and LDL cholesterol levels and increases HDL (Slentz et al., 2004; Woudberg et al., 2018). Regular exercise is strongly recommended to reduce the risk of cardiovascular complications by increasing HDL concentrations (Argani et al., 2014; Kodama, 2007; Kühnast et al., 2015; Woudberg et al., 2018). For future research, baseline lipid profile data should be collected to enable comparisons before and after exercise.

Body Composition

No significant differences were observed in body fat, total body water, muscle mass, or BMR from baseline to post-intervention across all groups (p>0.05). Acute aerobic exercise and the addition of recovery modalities do not appear to reduce body fat levels in either obese or non-obese subjects. Future studies should assess the long-term effects of aerobic exercise on body composition. Previous studies have demonstrated that long-term sauna use significantly reduces body fat percentage, body mass, and BMI in young men (Dąbek et al., 2009; Podstawski et al., 2021; Toro et al., 2021).

A significant reduction in visceral fat levels was observed in G1 across all modalities (p<0.05). Aerobic exercise combined with sauna significantly reduced visceral fat in obese subjects but not in non-obese subjects. A decrease in total body water was more frequently observed in obese individuals, although not significantly. Similarly, saunas were shown to reduce visceral fat and mineral levels in the body, though most weight loss was acute and attributable to fluid loss (transient dehydration) (Dąbek et al., 2009; Podstawski et al., 2021, 2022; Toro et al., 2021). Therefore, further observation is required to examine long-term effects.

A significant increase in bone mass was observed in G1 under the CTR modality and in G2 under the DS modality. Unique findings in body composition indicated significant differences between G1 and G2.

Obese subjects exhibited higher levels of body fat, visceral fat, muscle mass, BMR, and bone mass compared to non-obese subjects. In contrast, obese subjects had lower total body water compared to non-obese individuals. The magnitude of fluid loss tended to be greater in obese individuals with higher body mass, although proportionally the effect was similar in both groups (Podstawski et al., 2022).

BT

BT measurements were taken at regular intervals every 2 minutes during the 20-minute recovery modality administration. No significant differences in body temperature were observed across all modalities in both groups. The greatest increase in body temperature was recorded in DS, although this was not significantly different from the other modalities. While both DS and IRS provided heat exposure, IRS resulted in a lower body temperature compared to DS. IRS offers a more soothing experience, with milder and more comfortable heat exposure (Mero et al., 2015). Although sauna radiation may reach up to 45°C, the heat sensation is not very intense, and users tend to sweat more at lower temperatures with IRS compared to DS (Beever, 2009). These findings are consistent with previous research showing that the most significant increase in BT occurred after DS in all groups (Wiriawan, Kaharina, et al., 2024). Interestingly, heat administration through IRS and DS increased body temperature at the beginning of exposure but declined thereafter until the end of the session. In contrast, under CTR, body temperature continued to rise until the recovery period was complete.

Conclusions

The addition of a single recovery modality session did not result in significant changes in the lipid profile or body composition of subjects in either group. A significant decrease (p<0.05) in HDL levels was observed in G2 (IRS, CTR), along with a significant increase (p<0.05) in total cholesterol levels in G2 (IRS). These findings reflect the immediate effects of aerobic exercise; therefore, long-term studies are needed to further clarify the results. Distinct body composition findings showed significant differences between G1 and G2. Obese subjects exhibited higher levels of body fat, visceral fat, muscle mass, BMR, and bone mass compared to non-obese subjects, whereas total body water was lower in obese subjects. A significant reduction in visceral fat levels was observed in G1 (DS, IRS, CTR), but not in G2. Significant increases in bone mass were found in G1 (CTR) and G2 (DS). No significant differences in VAS values were observed across modalities in both groups. Based on the reduction in triglycerides (although not significant) and visceral fat levels, the addition of IRS after exercise is recommended for obese individuals. In non-obese individuals, passive recovery without additional modalities appears to be the most effective. Further research with longer intervention periods is necessary to complement these findings.

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