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CHANGES IN THE LIPID PROFILE OF BLOOD SERUM IN WOMEN TAKING SAUNA BATHS OF VARIOUS DURATION

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Abstract
Objectives: There is little information on lipid metabolism after sauna treatment in the literature. The present research is aimed to determine the influence of sauna baths on fat metabolism in young women. **Materials and Methods:** Twenty healthy, eumenhorreic, female volunteers (19–21 yr old) were exposed to Finnish sauna bath seven times every second day. In group I (n = 10) each time the sauna treatment lasted 30 min, whereas in group II (n = 10) 40 min with 5-minute break to cool down. Body mass, heart rate and blood pressure were measured before and after sauna bath. Rectal temperature was monitored during stay in sauna room. Prior to the sauna bath and during its last two minutes the minute oxygen uptake and the level of CO_2 exhalation were analyzed in the exhaled air, and the respiratory quotient RQ was calculated. In the blood samples collected before the sauna bath and immediately afterwards hematocrit, hemoglobin, and lipid profile — total lipids, free fatty acids, total free fatty acids, triacylglycerols, total cholesterol (TC), high density lipids (HDL), low density lipids (LDL) were analyzed. **Results:** Rectal temperature was lower in the last sauna bath than in the first one. Losses of plasma were greater during the seventh bath than during the first one. Acceleration of the metabolism of lipids occurs after every sauna bath. A reduced level of TC and LDLC and a raised level of HDL was observed after repeated sauna baths. **Conclusion:** After 2 weeks of repeated sauna session some changes in total cholesterol and concentration of LDLC were observed, while concentration of HDLC increased after 7th sauna bath in group I. Those kinds of changes may be good prognoses of ischemic heart disease prevention, but further research on the influence of sauna on fat metabolism is needed.

Key words:
Lipid profile of blood serum, Sauna

INTRODUCTION

The proper concentration of individual elements of the lipid profile of blood serum is a significant factor in preventing atherosclerosis and, in consequence, the development of myocardial ischemia. The results of the research conducted so far show that regular physical activity has a beneficial effect on the changes in the lipid profile, which takes the form of a decreased level of LDL and TG concentration in blood serum [1,2].

Sauna baths may relieve pain in musculoskeletal disorders and improve joint mobility in patients with rheumatic disease [3,4]. Sauna treatment has not appeared to be of risk for patients with hypertension, coronary heart disease and congestive heart failure when they are in stable medical

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condition owing to medication [4]. Moreover, there are studies suggesting that long-term sauna bathing may help lower blood pressure and can be an effective therapeutic modality for patients with cardiovascular disease, especially for patients with congestive heart failure, improving vascular endothelial function and the left ventricular ejection fraction [3,5,6].

Nowadays sauna is an important factor in biological regeneration and it is used both by athletes and people who do not practice any sport. In sport, it is very often used as one of the training modalities [7–12]. It activates many body systems, including the endocrine system [4,13–17]. The increase in the carbohydrates utilization, being a result of the increase in lactates concentration under thermal stress, was observed by many researchers [13,14,18–20] and it can be explained by increased glycolysis. The conclusion which can be drawn from the majority of research works on the influence of sauna on the human body conducted in Scandinavian countries on volunteers using sauna on a daily basis is that overheating causes the shifting of metabolism toward carbohydrate changes [21–24]. The researchers, however, did not analyze lipid metabolism and, therefore, the present research is aimed at the comparison of physiological reactions and changes in the lipid profile of blood serum, depending on the duration of sauna baths.

METHOD

The subjects were 20 volunteers — healthy women (with a doctor's health certificate), non-smokers, at the age of 19–21. They did not practice any sport and had not used sauna before. The research project was approved of by the Ethical Committee at the Medical Academy in Kraków. The subjects who were qualified did not report any menstrual irregularities and the experiment started when they were in the first (follicular) phase of their menstrual cycle. None of the subjects used any hormonal contraception.

Prior to the experiment, an interview was carried out during which the subjects were asked questions regarding their dietary habits. The condition of their nutrition was assessed from the answers they gave to questions regarding food intake within 24 hours [25]. The quantity of the consumed food was assessed using Album of Photography of Products and Dishes [26]. On the basis of the results of the interview, the nutrition of the subjects was evaluated using the computer program Wikt 1 and the Tables of Nutritious Value of Food Products [27]. The nutritional value of the food was calculated taking into consideration relevant coefficients of losses connected with technological processes. The mean daily energetic value and the main nutrients of the food consumed by the subjects were calculated.

The subjects were divided into two groups of ten. The first group (Group I) took seven Finnish sauna baths every other day, always in the morning. Each time the sauna treatment lasted 30 min, and the subjects were in a half-lying position. The other group (Group II) took a similar series of baths, in an identical cycle; the only difference was that their baths lasted 40 minutes each, divided into 2 periods of 20 minutes, with a 5-minute break between them. During that break the subjects left the sauna room and took a cold shower (20–22°C) for 2 minutes and then rested in a half-lying position. The temperature in the sauna was 80.1°C on the average and the relative humidity of the air was 5–26.6%.

All physiological and biochemical measurements were made on the first day of the experiment (before and after the first thermal bath) and on the fourteenth day (before and after the last, seventh, thermal bath). On those two days the subjects came after a night's rest and with an empty stomach.

The following physiological indices were determined during the research: (HR) heart rate (beats×min^{-1}), (SBP) systolic blood pressure (mm Hg), (DBP) diastolic blood pressure (mm Hg), (Tre) rectal temperature (°C), (Tty) tympanic temperature (°C), and (BW) body weight (kg).

The heart rate was determined using palpation and the blood pressure was taken with a mercury sphygmomanometer. The rectal and tympanic temperatures were monitored using electro-thermometer (Ellab, Danmark) to an accuracy of 0.1°C.

The body mass was determined by means of Sartorius electronic scales before the subjects entered the sauna and at the end of the thermal bath. In order to determine the respiratory indices prior to the sauna bath and during its last two minutes, the exhaled air was collected into Douglas bags and subsequently analyzed using a Beckman MMC apparatus. The results were used to calculate the per-minute oxygen uptake, the level of CO_2 exhalation and the respiratory quotient RQ.

Blood samples of 10 cm^3 were taken for biochemical analysis from a vein on the front side of the elbow joint 10 minutes before the sauna bath and immediately afterwards. The following biochemical parameters were determined in the venous blood: (Hct) hematocrit, using the microhematocrit method and (Hb) hemoglobin concentration, using the Drabkin method. The changes in the blood plasma volume were calculated from the changes in the hematocrit values and hemoglobin concentration according to the following formula:

$$\% \text{ Delta PV} = 100 \{(Hb1/Hb2) \times [100–(Hct2 \times 0.874)] / [100–Hct1 \times 0.874)]–1\}$$

where Hb1 (g/dl) and Hct1 (%) are the initial values and Hb2 and Hct2 are the final values. Hct was multiplied by 0.96 and 0.91, that is correction coefficients for the trapped plasma and peripheral blood.

In order to determine the changes in lipid metabolism in the blood serum, the following substances were determined: total lipids (TL), free fatty acids (FFA), total free fatty acids (TFFA), triacylglycerols (TG), total cholesterol (TC), high density lipids (HDL), low density lipids (LDL). The concentration of lipids after sauna baths was corrected taking into consideration the decrease in plasma volume.

STATISTICS

The obtained data were presented as mean arithmetic values ±SD. Statistical significance of the results obtained within one group was checked using the Wilcoxon's test for two dependent groups. It was also checked, using the non-parametric Wilcoxon's test for two independent groups, to see whether there were statistically significant differences between the initial anthropometric, physiological and biochemical indices of subjects from groups I and II. All the calculations were done using the Statgrafics package for IBM PC.

RESULTS

The general profile of the subjects is presented in Table 1. It shows that there was no significant difference in anthropometric indices between the women from groups I and II.

The results of dietary habits assessment are presented in Table 2. The mean daily energetic value and the main nutrients of the food consumed by the subjects did not differ significantly from those considered to be normal for women of that age group [28].

Table 2. Mean daily energetic value and nutritional elements of the subjects' diet (n = 20) ($\bar{x}$ ±SD)

Nutrients	Energetic values
Energy (kcal)	2 467.30±446.76
Proteins (g)	94.30±18.64
Fats (g)	107.36±13.82
Carbohydrates (g)	440.12±47.68

The changes in physiological parameters in both groups of subjects during the 1st and the 7th bath are presented in Table 3.

Table 1. Characteristics of participants

Parameter	Group I (30')				Group II (45')			
	min	max	mean	SD	min	max	mean	SD
Age (year)	19.00	21.0	19.8	0.92	19.00	20.0	19.8	0.42
BH (cm)	158.00	173.0	163.9	4.72	154.00	175.0	165.8	6.46
BM (kg)	49.36	66.6	58.4	5.81	50.88	69.1	60.0	6.67
BMI (kg/m^2)	19.28	24.5	21.7	1.62	19.39	26.0	21.8	1.93
PF (%)	15.22	30.5	23.2	4.61	20.94	26.3	23.9	2.13
FM (kg)	9.20	20.2	13.6	3.59	10.87	16.8	14.3	1.88
LBM (kg)	38.91	51.3	44.8	4.32	37.51	52.5	45.7	4.97

SD — standard deviations.

Table 3. Physiological parameters after the 1st and 7th sauna

Parameters		First bath in sauna			Seventh bath in sauna		
		before	after	delta	before	after	delta
BM (kg)	Group I	58.36±5.80	57.80±5.80	–0.55*	58.57±5.70	58.01±5.70	–0.56*
	Group II	60.03±6.70	59.35±6.60	–0.68*	59.88±6.30	59.21±6.30	–0.67*
Tre (°C)	Group I	37.30±0.30	38.40±0.30	1.10*	37.1±0.30	38.10±0.40	1.00*
	Group II	37.10±0.30	38.10±0.50	1.10*	37.0±0.40	37.80±0.30	0.80*
HR ($sk.\times min^{-1}$)	Group I	68.00±8.90	122.00±15.00	54.00*	66.00±10.40	106.00±15.80	40.00*
	Group II	67.00±10.6	118.00±18.10	51.00*	61.00±10.50	96.00±9.70	35.00*
ΔPV (%)	Group I	–	–	–8.00*	–	–	–9.50*
	Group II	–	–	–4.66*	–	–	–6.14*
VE ($1\times min^{-1}$)	Group I	6.46±1.52	14.31±4.30	7.85*	6.15±1.40	11.12±5.60	4.97*
	Group II	6.48±2.08	10.94±3.70	4.46*	6.39±1.40	9.01±2.10**	2.60*
VO_2 ($1\times min^{-1}$)	Group I	0.237±0.05	0.407±0.20	0.17*	0.236±0.04	0.331±0.10	0.095*
	Group II	0.228±0.05	0.333±0.60	0.105*	0.23±0.06	0.295±0.02	0.065*
FE CO_2 ($1\times min^{-1}$)	Group I	0.203±0.05	0.371±0.09	0.168*	0.203±0.49	0.295±0.11	0.092
	Group II	0.192±0.49	0.30±0.070	0.108*	0.189±0.41	0.227±0.09	0.038
RQ	Group I	0.82±0.07	0.92±0.10	0.10	0.85±0.09	0.87±0.10	0.02
	Group II	0.85±0.05	0.89±0.10	0.04	0.83±0.07	0.76±0.06	–0.07

* $p < 0.05$.
** $p < 0.05$ — after 1st vs. 7th sauna.

After each sauna bath, there was a statistically significant decrease in the body mass of the subjects, which was more evident in group II who took 40-minute baths compared to group I, whose baths lasted 30 minutes. Before entering the sauna the rectal and tympanic temperature of the subjects was always normal. After each sauna bath a statistically significant increase in both rectal and tympanic temperature was observed and it was more pronounced in the group II who took longer baths with a break to cool down. Besides, during the last sauna bath there was a statistically significant, lower than during the first bath, increase in both rectal and tympanic temperature in both groups of subjects. In both groups of subjects the heart rate also increased significantly after the first bath. The increase in the value of heart rate after the last bath was significantly lower than after the first exposure to high temperature.

Systolic blood pressure increased significantly as a result of thermal stress in both groups, both after the first and the last thermal exposure. Diastolic pressure decreased in a statistically significant way as a reaction to overheating the organism in both groups of subjects after each sauna bath. The decrease in the plasma volume noted during the first sauna bath was significantly higher in the subjects who took a 30-minute baths than in the other group with longer thermal exposure and a break to cool down (group II). During the last bath the decrease in the plasma volume was significantly lower than during the first bath in both groups of subjects. A single sauna bath caused a statistically significant increase in ventilation and the level of carbon dioxide exhalation in both groups of subjects and it was less intense during the last bath. The changes in the respiratory quotient (RQ) were slight in both groups of subjects and were not statistically significant. The changes in lipid concentration after sauna baths are presented in Table 4.

The changes in triglyceride and total cholesterol concentrations were slight in both groups of subjects and were not statistically significant. After the first bath, in the group whose exposure lasted 30 minutes there was noted

Table 4. Changes in lipid profile after the 1st and 7th sauna bath

Lipids		First bath in sauna			Seventh bath in sauna		
		before	after	delta	before	after	delta
TG ($mmol \times l^{-1}$)	Group I	0.74±0.30	0.74±0.30	0	0.70±0.5	0.99±0.30	0.02
	Group II	0.75±0.20	0.66±0.20	–0.09	0.72±0.2	0.71±0.10	–0.01
FFA ($mmol \times l^{-1}$)	Group I	0.69±0.30	1.07±0.30	0.38**	0.62±0.2	0.84±0.30	0.22
	Group II	0.66±0.30	0.72±0.20	0.06****	0.66±0.4	0.85±0.40	0.19
TC ($mmol \times l^{-1}$)	Group I	4.44±0.80	4.52±0.70	0.09	4.23±0.9	4.34±0.90	0.11
	Group II	4.64±0.82	4.50±0.80	–0.18	4.25±0.3***	4.12±0.70	–0.13
HDL (HDLC) ($mmol \times l^{-1}$)	Group I	1.28±0.30	1.38±0.30	0.10	1.10±0.2	1.20±0.20	0.10*
	Group II	1.49±0.30	1.42±0.20	–0.07	1.42±0.3****	1.39±0.40****	–0.02
LDL (LDLC) ($mmol \times l^{-1}$)	Group I	3.01±0.80	3.00±0.80	–0.01	2.93±0.9	2.96±0.80	0.03
	Group II	2.85±0.80	2.78±0.80	–0.07	2.50±0.6	2.40±0.60	–0.10

* $p < 0.05$.
** $p < 0.01$ — before vs. after sauna.
*** $p < 0.05$ — before 1st vs. before 7th sauna.
**** $p < 0.05$ — Group I vs. Group II.

a statistically significant increase in FFA concentration. After the last bath, a statistically significant increase in HDL cholesterol was observed.

DISCUSSION

Sauna baths cause an increase in metabolic rate resulting from excitation of the sympathoadrenal system, hormonal changes and increased internal temperature of the body [7,9,15,23]. In the accessible reference material, there is little information regarding the trends of metabolic changes in the specific conditions of the human body overheated in the Finnish sauna. The regulation of the speed of metabolic changes in the human body depends mainly on the functioning of the nervous and endocrine systems and the activity of key enzymes in the cells of peripheral tissues. The hormones influence the lipid metabolism mainly by regulating the speed of key enzyme synthesis and modification of the activity of those enzymes. The research on the influence of sauna on the hormonal balance conducted on female subjects showed an increase in the concentration of such hormones as ACTH, cortisol, and hGH after sauna baths [14].

The authors of the present study did not notice any changes in the level of total lipids or triglycerides after single or repeated thermal treatment in sauna bath. Triglycerides described as neutral fats are esters of glycerol and fatty acids and the main place of their accumulation is in the adipocytes. They are synthesized in the liver, adipose tissue and intestine epithelium cells and their main role is to store energy. Triglycerides are transported in blood mainly as chylomicrons and lipoproteins belonging to the VLDL group produced in the liver. The influence of overheating on the TG level is not unequivocally determined. There was observed both the increase in the concentration of those lipoids in male subjects after a single overheating of the body in the sauna [19] and the lack of such increase [13].

Rovensky et al. [29] noted an increase in the amount of triglycerides and lipoproteins of very low density (VLDL) after 30 minutes' overheating in water. They consider it a very interesting phenomenon which can, however, lead to the development or premature occurrence of atherosclerosis due to the fact that lipoproteins rich in triglycerides have an atherogenic effect.

This hypothesis, however, was not confirmed by other studies and in the view of the results of the present research it seems to be irrelevant, at least as far as women are concerned. The authors of the present research noted an increase in the concentration of free fatty acids after

a single sauna bath (particularly intense in group I) and after the last, seventh hyperthermia, which ended the 2-week experiment.

Free fatty acids constitute the main form of fatty acids transportation from adipose tissue to the majority of internal organs for metabolic and structural purposes and they play a major role in metabolism as one of basic energetic substrates. Free fatty acids are a lipid fraction of very short duration — about 2 to 3 minutes — and their level in the blond serum is changeable and depends on many factors, mainly on the metabolic conditions of the organism. The concentration of free fatty acids increases during fasting and physical effort. The factors intensifying lipolysis in adipose tissue cells, increasing thereby the concentration of FFA in blood are glucagon, catecholamines, ACTH, cortisol, growth hormone and the activity of sympathetic nervous system. Glucose and insulin, on the other hand, are factors inhibiting lipolysis and stimulating the process of lipogenesis. The increase in the secretion of lipolytic hormones, such as hGH, ACTH, cortisol and prolactin, which can be responsible for the increase in FFA, had been described before [14,16]. The increase in catecholamine and glucagon secretion, described by other researchers, as well as stimulation of the sympathetic part of the autonomic nervous system constitute other factors which activate lipolysis in thermal stress conditions [4,15,21,22,30]. Inhibition of insulin secretion and elevation of insulin resistance to glycemia are the factors which decrease lipogenesis [21,22], a process lowering the level of FFA in peripheral blood. The increase in the FFA concentration as a result of overheating in sauna may, therefore, be a result of both intensification of lipolysis and decreased lipogenesis. Changes in cholesterol fractions as a result of single and repeated thermal sauna baths should also be mentioned, since they constitute a risk factor for ischemic heart disease.

The authors of the present study noticed a decrease in total cholesterol concentration assessed before entering the sauna (when the stomach was empty) and reduced level of LDL cholesterol after 2 weeks of repeated sauna baths, which was particularly noticeable in group II, in which the level of stress was much lower. At the end of the 2nd week of the experiment, it was also noticed that the level of HDL cholesterol concentration increased after overheating in the sauna, more prominently in Group I. These changes may constitute a good prognosis for prevention of cardiovascular disease since a close positive correlation has been demonstrated to occur between the level of total cholesterol and susceptibility to cardiovascular disease [31]. There is a similar dependence between the level of LDL cholesterol, called “bad cholesterol”, and susceptibility to cardiovascular disease, whereas a reverse relationship exists between HDL cholesterol (“good cholesterol”) and the quoted heart disease [31,32].

At present, one should be careful in drawing any far-reaching conclusions from the research regarding the described changes in lipids, since Vangelova et al. have described the unfavorable changes in the serum lipids in workers exposed to heat for a long time [33]. It seems, however, that there is a need for further research on the influence of sauna on fat metabolism in the human body with bigger groups, both sexes and more sauna sessions. It would be also interesting to observe changes in lipid for some weeks following sauna bathing.

CONCLUSIONS

1. After a single sauna bath there is a significant increase in FFA concentration in group I, attributable probably to increased adrenergic stimulation.
2. After 2 weeks of repeated sauna baths the authors observed a decrease in total cholesterol concentration and LDL cholesterol concentration, while the HDL cholesterol concentration increased, which could be a good prognosis for prevention of cardiovascular disease, but further research on the influence of sauna on fat metabolism is needed, including also male participants.

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