sciendo

Original Paper

Biomedical Human Kinetics, 15, 289–297, 2023
DOI: 10.2478/bhk-2023-0035

Effect of 8 days of water-only fasting and vigorous exercise on anthropometric parameters, lipid profile and HOMA-IR in middle-aged men

Karol Pilis[1], Anna Pilis[1], Krzysztof Stec[1], Jędrzej Antosiewicz[2], Andrzej Ślęzak[1], Jolanta Zalejska-Fiolka[3], Paweł Dolibog[4], Wiesław Pilis[1], Sławomir Letkiewicz[1]

[1] Collegium Medicum, Jan Długosz University in Częstochowa, Częstochowa, Poland; [2] Department of Bioenergetics and Physiology of Exercise, Medical University of Gdańsk, Gdańsk, Poland; [3] Department of Biochemistry, Faculty of Medical Science in Zabrze, Medical University of Silesia, Katowice, Poland; [4] Department of Biophysics, Faculty of Medical Sciences in Zabrze, Medical University of Silesia, Katowice, Poland

Abstract

Study aim: The aim of the present study was to determine the effect of 8 days of water-only fasting and physical exercise on somatic variables, lipid profile, insulin resistance and cardiovascular function in middle-aged men.
Material and methods: Body weight, body composition, lipid profile, serum concentrations of insulin, glucose, β-hydroxybutyrate (β-HB), heart rate (HR), blood pressure and the homeostasis model assessment of insulin resistance (HOMA-IR) were determined in 16 apparently healthy men at rest and after aerobic exercise. This test procedure was also repeated after 8 days of water-only fasting.
Results: Fasting intervention resulted in a reduction in body weight and fat mass ($p < 0.001$). The simultaneous effect of fasting and exercise resulted in significant changes in lipid profile, carbohydrate metabolism and cardiovascular function. Post hoc analyses showed that the reductions in insulin and glucose concentrations as well as the HOMA-IR index were caused by the fasting, and changes in the lipid profile and cardiovascular function were caused by the exercise test.
Conclusion: The combined use of fasting and physical effort resulted in an optimal effect on health indicators of the surveyed men.

Keywords: Fasting – Exercise – Anthropometric parameters – Lipid profile – Carbohydrate metabolism – Cardiovascular function

Introduction

The most common form of fasting is calorie restriction (CR), and a variation of it is intermittent fasting (IF), which includes alternate-day fasting (ADF), whole-day fasting (WDF), and time-restricted feeding (TRF). There is also complete fasting, understood as only taking water ad libitum. Metabolic changes occurring during complete fasting became the basis for separating three phases in this process: postabsorptive, gluconeogenic and conservation of protein phase [30]. The mentioned forms of fasting cause e.g. somatic and functional changes, and changes in the lipid profile or carbohydrate metabolism [4, 35].

The most easily observed effect of fasting is weight loss, which is also associated with a decrease in fat content and often with lower fat-free mass (FFM). These changes were observed after complete fasting [25], after CR and IF [17, 40], and after ADF. After 12 weeks of using ADF combined with endurance exercises and ADF alone, body weight of obese people decreased by 6.0 ± 4.0 kg and 3.0 ± 1.0 kg, respectively, and fat mass and waist circumference were also significantly reduced, with FFM unchanged only in the first group [5]. Significantly greater somatic changes were caused by 50-day starvation, after which body weight was reduced by 21.11% and BMI by 21.19% [9].

It is also postulated that fasting can be a form of therapy supporting the fight against dyslipidemia. It has been shown that IF improves the lipid profile of healthy, obese and dyslipidemic people [37]. During ADF maintained for 2–3 weeks, the levels of triglycerides (TG), total

Author's address Anna Pilis, Collegium Medicum, Jan Długosz University in Częstochowa, Częstochowa, Poland
a.pilis@ujd.edu.pl

cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) decreased, which reduced the risk of developing coronary heart disease [5]. The existing data on changes in the lipid profile and the resulting health effects are, however, fragmentary and most often come from the observation of fasting during Ramadan [1].

Since it has been shown that after 24 hours of fasting, liver glycogen is depleted [34] and there is a significant increase in the concentration of fatty acids and ketone bodies in the blood, the view was put forward that these factors increase insulin resistance [11]. On the other hand, numerous studies using CR, TRF, IF, ADF or ADF in combination with physical exercise have shown decreased insulin levels and improved insulin sensitivity [3, 14, 17, 39, 41] or reduced glucose levels [3, 17]. There was also a decrease in HOMA-IR, considered an indicator of insulin resistance [5, 14, 16, 17].

The described metabolic conditions during fasting determine the plasma composition, which results in changes in the cardiovascular system [39]. These changes strongly affect blood pressure and heart rate [47].

Another factor significantly influencing the change in body weight, lipid profile, carbohydrate metabolism, and function of the circulatory system is physical exercise of an intensity that is at least moderate. Relatively little is known about changes in weight and body composition under the influence of a single exercise. The greatest changes occur during intense efforts lasting several hours [28, 38].

In terms of metabolic effects of a single physical effort, it was found that a 48-hour ultramarathon run reduced the concentrations of TC, LDL-C and TG and increased the concentration of HDL-C [24]. It was also observed that one-time physical exercise improved the ability of insulin to take up glucose [13]. This effect was associated with the post-exercise depletion of muscle glycogen [34] and persisted several hours after exercise cessation [20]. The mechanism of the described changes has not yet been thoroughly explained, and it is only suggested that it is related to the improved ability of insulin to stimulate the translocation of glucose transporters (GLUT4) to the skeletal muscle membrane after exercise [13].

The impact of rational physical effort on the circulatory system of healthy people is positive, while the physical effort load of sick people requires care. The use of physical effort in the diagnosis of various diseases should also be emphasized [2].

Since it is known that various forms of fasting and physical activity have a pro-health effect, it was decided to examine the effect of 8 days of water-only fasting and a single physical effort on changes in weight and body composition, lipid profiles, homeostasis model assessment of insulin resistance (HOMA-IR) and cardiovascular function in apparently healthy middle-aged men. Therefore, the hypothesis was formulated that both of these factors protect against negative health changes.

Materials and methods

Subjects

The study included 16 apparently healthy male volunteers, aged 53.38 ± 13.73 years, who were white collar workers. Prior to the start of the study, the volunteers underwent medical examinations. The exclusion criteria were: (1) nicotine addiction; (2) taking drugs, stimulants or psychoactive substances; (3) failure of the men surveyed to complete the research procedure; (4) the occurrence of chronic diseases. The surveyed men had already practiced fasting of various lengths; the last fasting intervention was carried out 6 months ago. Before the study began, all volunteers were on a mixed diet with a small amount of meat for 3 days. All participants of the study were informed about the conditions that had to be met before the initial test procedure (no consumption of alcohol or vigorous exercise for 48 hours before the measurements; no consumption of food and drinks for 12 hours before the measurements).

The research was approved by the Ethical Research Committee of the Jan Długosz University in Częstochowa, in accordance with the requirements of the Helsinki Declaration. The somatic characteristics of the studied men are presented in Table 1.

Table 1. Age and somatic variables before and after fasting.

Parameter	Before	After	
	Mean ± SD	Mean ± SD	Changes [%]
Age	53.38 ± 13.73	53.38 ± 13.73	–
BW [kg]	81.74 ± 11.47	75.82 ± 10.99***	–7.29
BH [cm]	178.44 ± 4.50	178.44 ± 4.50	–
BF [kg]	16.53 ± 5.93	14.65 ± 5.93***	–11.43
BF [%]	20.30 ± 5.15	18.61 ± 5.86**	–8.24
FFM [kg]	65.21 ± 5.95	61.06 ± 5.83***	–6.32
FFM [%]	80.39 ± 5.17	81.20 ± 5.75*	+1.00
TBW [kg]	47.75 ± 4.35	44.78 ± 4.11***	–6.09
TBW [%]	58.87 ± 3.78	59.58 ± 4.30**	+1.20
BMI [kg/m^2]	25.69 ± 3.64	23.82 ± 3.40***	–7.41

BW – body weight; BH – body height; BF – body fat; FFM – fat-free mass; TBW – total body water; BMI – body mass index. Different than before *** – $p<0.001$, ** – $p<0.01$, * – $p<0.05$,

Procedure

All research procedures were performed in the morning, after an overnight fast, and are presented in Fig. 1.

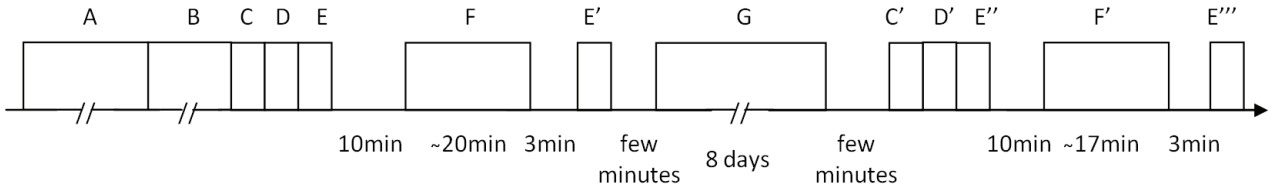


Figure 1. Scheme of the research procedure

A – 3 days of mixed diet; B – 12 hours fast; C,C' – somatic measurements; D,D' – circulatory measurements; E,E',E'',E''' – blood collections; F,F' – exercise tests; G – 8 days of water-only fasting.

In the first stage of the study, the age of the participating men and their somatic variables, which included body weight (BW), body fat (BF), fat-free mass (FFM), total body water (TBW) and body mass index (BMI), were recorded. Then, at rest, heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded. Blood samples were collected from the cubital vein under laboratory conditions and initially stored at room temperature for up to a maximum of 10 minutes, during which hematocrit (Ht) was measured. In the next step, the blood was centrifuged at 15,000 x g for 15 min, and the obtained serum samples were frozen at – 80°C and stored for further analysis. In these samples, the concentrations of total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), insulin, glucose and β-hydroxybutyrate (β-HB) were determined. Levels of non-high-density lipoprotein cholesterol (nHDL-C) and low-density lipoprotein cholesterol (LDL-C) were also calculated. The LDL-C variable was calculated using the Friedewald formula [12]. The concentration of nHDL-C was calculated from the formula: nHDL-C = TC – HDL-C. The risk of cardiovascular disease (CVD) was additionally assessed by calculating the following ratios: TC/HDL-C (R_1), LDL-C/HDL-C (R_2), TG/HDL-C (R_3), nHDL-C/HDL-C (R_4). Plasma atherogenic index was also calculated from the formula: R5 = log10TG/HDL-C [8].

The homeostatic model assessment of insulin resistance (HOMA-IR) was defined as fasting serum insulin (milliunit per liter) multiplied by fasting glucose (millimole per liter) divided by 22.5 [46].

Then, the examined men were subjected to an ergometric exercise test. This test was started at an intensity of 30 W, and each successive load was increased by 30 W (which lasted 3 minutes) until maximum exercise capacity was reached. HR, SBP, DBP and respiratory variables were recorded in the final seconds of each exercise load. Three minutes after the end of the exercise test, blood was taken again and the analyses described above were performed. After completing the research procedures, the men proceeded to fast, during which they consumed only any amount of the same water with a total mineral content of approximately 1900 mg/l. After 8 days of fasting, the research procedure described above was repeated.

Methods

Somatic measurements were determined by means of bioelectrical impedance analysis using a commercially available body composition analyzer (Type BF-300, TANITA Corporation, Tokyo, Japan). Body height was measured using the A-226 anthropometer (Tristom, Olomouc, Czech Republic). TC was determined by the spectrophotometric method, and HDL-C and TG concentrations were determined by colorimetry, using reagents from Spinreact (Spain). Serum insulin concentration was determined with the immunoradiometric method using Immunotech SA (France) kits, while enzymatic methods were used to determine glucose and β-HB levels using commercially available diagnostic kits from Randox (UK).

Statistical analyses

Basic statistical analyses of all variables were performed and the mean (M) and standard deviation (±SD) were calculated. The Shapiro-Wilk test was used to check the normality of the distribution. The paired t-test was used to determine the effect of 8 days of water-only fasting on somatic variables. Friedman repeated measures analysis of variance by ranks with the Dunn-Bonferroni post hoc test was used to show differences between the results recorded before and after 8 days of water-only fasting and exercise testing. Values of $p < 0.05$ were considered statistically significant. All statistical analyses were performed using the STATISTICA software (Dell Statistica – data analysis software system, version 13.3).

Results

Eight days of water-only fasting resulted in significant changes in the following variables: BW, BF, FFM, TBW and BMI – Table 1. In addition, fasting and exercise changed: TC, HDL-C, TG ($p < 0.001$), nHDL-C ($p < 0.01$), LDL-C ($p < 0.05$) – Table 2; insulin, glucose, HOMA-IR, β-HB ($p < 0.001$) and Ht ($p > 0.05$) – Table 4; HR, SBP ($p < 0.001$), and DBP ($p < 0.01$) – Table 5. Exceeding the upper limits of reference values before the start of the fasting intervention occurred in relation to: TC, nHDL-C, LDL-C – Table 2; ratio R4 – Table 3.

Table 2. Lipid profile responses to fasting and exercise (M ± SD)

Parameter	Rest before fasting(1)	Rest after fasting(2)	Exercise before fasting(3)	Exercise after fasting(4)	Friedman's Anova p
T-C [mg/dl]	220.8 ± 60.7	223.9 ± 71.65	241.7 ± 61.3**	241.25 ± 74.8	0.0007
HDL-C [mg/dl]	52.63 ± 8.97	53.56 ± 8.70	57.38 ± 9.96**	58.56 ± 10.01#	0.0001
nHDL-C [mg/dl]	168.1 ± 57.9	170.4 ± 68.8	184.3 ± 58.5**	182.7 ± 69.6	0.0013
LDL-C [mg/dl]	146.9 ± 51.6	148.4 ± 66.4	160.1 ± 53.0*	156.28 ± 66.9	0.0231
TG (M) [mg/dl]	106.2 ± 64.6	110.5 ± 30.6	120.8 ± 65.9	132.1 ± 34.4#	0.0002

Dunn-Bonferroni comparisons: different than (1) ** – $p < 0.01$, * – $p < 0.05$; Different than (2) # – $p < 0.05$.

Table 3. Responses of cardiovascular risk factors to fasting and exercise (M ± SD)

Parameter	Rest before fasting(1)	Rest after fasting(2)	Exercise before fasting(3)	Exercise after fasting(4)	Friedman's Anova p
R1 = T-C/HDL-C	4.23 ± 1.04	4.21 ± 1.10	4.27 ± 1.01	4.12 ± 0.89	0.9134
R2 = LDL-C/HDL-C	2.81 ± 0.89	2.79 ± 1.04	2.83 ± 0.86	2.66 ± 0.85	0.2483
R3 = TG/HDL-C	2.08 ± 1.33	2.12 ± 0.68	2.19 ± 1.34	2.31 ± 0.66	0.0557
R4 = nHDL-C/HDL-C	3.23 ± 1.03	3.19 ± 0.89	3.21 ± 1.10	3.13 ± 0.89	0.7829
R5 = log10 TG/HDL-C	0.25 ± 0.21	0.30 ± 0.15	0.28 ± 0.24	0.34 ± 0.14	0.1195

Table 4. Metabolite concentrations and hematocrit values in relation to applied fasting and exercise. (M ± SD)

Parameter	Rest before fasting(1)	Rest after fasting(2)	Exercise before fasting(3)	Exercise after fasting(4)	Friedman's Anova p
Insulin [mU/L]	6.57 ± 1.54	4.65 ± 1.76	6.68 ± 1.53	3.81 ± 1.53+++	0.0001
Glucose [mmol/l]	5.01 ± 0.56	3.83 ± 0.64^^	5.78 ± 0.76	4.57 ± 0.68++	0.0001
HOMA-IR[mU/mmol]	1.47 ± 0.41	0.82 ± 0.43^	1.71 ± 0.42	0.80 ± 0.40+++	0.0001
β-HB [mmol/l]	0.30 ± 0.20	4.30 ± 1.42^^^	0.21 ± 0.15	3.68 ± 1.34++	0.0001
Hematocrit [%]	44.14 ± 3.59	43.43 ± 3.76	44.71 ± 3.45	43.93 ± 3.41	0.5574

Dunn-Bonferroni comparisons: Different than (1) ^^^ – $p<0.001$, ^^ – $p<0.01$, ^ – $p<0.05$; Different than (2) +++ – $p<0.001$, ++ – $p<0.01$.

Table 5. Cardiovascular responses to fasting and exercise. (M±SD)

Parameter	Rest before fasting(1)	Rest after fasting(2)	Exercise before fasting(3)	Exercise after fasting(4)	Friedman's Anova p
HR [bpm]	63.50 ± 8.91	70.94 ± 12.65	162.00 ± 16.88***	161.31 ± 13.53###	0.0001
SBP [mmHg]	127.50 ± 14.4	115.63 ± 14.24	189.06 ± 24.24***	172.81 ± 23.38###	0.0001
DBP [mmHg]	83.13 ± 9.81	77.81 ± 8.16	76.25 ± 10.08	75.63 ± 8.54	0.0086

Dunn-Bonferroni comparisons: Different than (1) *** – $p<0.001$; Different than (2) ### – $p<0.001$.

Eight days of water-only fasting did not change the lipid profile, but the physical test itself did. Physical exercise increased the concentrations of TC, HDL-C, nHDL-C ($p < 0.01$), as well as LDL-C ($p < 0.05$) before the fasting intervention, and HDL-C and TG ($p < 0.05$) after this intervention.

On the other hand, the concentration of insulin decreased significantly as a result of using 8 days of water-only fasting only after physical exercise ($p < 0.001$), while the concentration of glucose and HOMA-IR index decreased significantly both in the conditions of rest and exercise. In addition, the fasting intervention caused

a significant ($p < 0.001$) increase in β-HB concentration both at rest and after exercise. However, after the fasting intervention and after the exercise test Ht decreased, but these changes were not statistically significant.

In terms of cardiovascular function, there was a significant increase in HR and SBP, caused by exercise, both before and after 8 days of water-only fasting.

It was also found that under the influence of fasting intervention, the maximum power developed during the ergometric test and the duration of this test were significantly reduced ($p < 0.05$). Before 8 days of water-only fasting they were 208.13 ± 38.68 W and 20.81 ±3.87 min, respectively, and after this intervention they were 176.25 ± 34.42 W and 17.63 ± 3.44 min.

Discussion

Fasting, similarly to physical effort, may have a health-promoting effect [50]. In both of these conditions, increased carbohydrate and fat catabolism is observed [31]. On the other hand, the metabolic and functional effects of physical exercise are observed almost immediately after its initiation, and the effects of fasting are noticeable only after a few hours or even several days.

Changes in the lipid profile after fasting and exercise

Exceeding the upper limits of reference norms in the examined men at rest in the period before fasting intervention in relation to TC, LDL-C and nHDL-C suggests that these people should be included in the group with mild hypercholesterolemia. This suggestion is also confirmed by the increased R4 ratio, which plays an important role in the diagnosis and progression of coronary heart disease [49]. Significant changes in the plasma lipid profile occurred as a result of concomitant use for 8 days of water-only fasting and in the progressive exercise test, when changes in TC, HDL-C, nHDL-C, LDL-C and TG were observed. It is often pointed out that cholesterol and individual serum lipoprotein concentrations are less useful markers in predicting the risk of cardiovascular disease than such indices as log 10 TG/HDL-C, TC/HDL-C, LDL-C/HDL-C and TG/HDL-C [7, 8]. In our research, the discussed indicators, although they mostly fell within the reference ranges, did not change significantly under the influence of 8 days of water-only fasting and the exercise test. Only a strong, unfavorable, upward trend of the R_3 index was observed, which in the studies of other authors was significantly reduced during the ultramarathon run, which was considered a favorable change in the lipid profile [24]. It should be noted that tracking changes in this indicator is important because it can be helpful in identifying insulin resistance and metabolic syndrome [23, 33]. A post hoc analysis showed that a greater contribution to changes in the lipid profile should be attributed to physical exercise than to fasting intervention. The exercise test resulted in an increase in the concentrations of TC, HDL-C, nHDL-C, LDL-C before the fasting intervention and HDL-C and TG after this intervention. Similar changes in the lipid profile were also observed in our earlier study in middle-aged men [32]. These effects are related to the significant stimulation of fat metabolism occurring during exercise loads [36].

On the other hand, the lack of an increase in post-exercise concentrations of TC, nHDL-C and LDL-C in the conditions of 8 days of water-only fasting indicates limited oxidation of these lipids. Therefore, it is not clear whether the observed post-exercise changes in the lipid profile after 8 days of water-only fasting result from the effect of the fasting intervention or are caused by the shorter duration and lower intensity of the exercise used than before the fasting period.

Also, the results of studies by other authors did not clearly answer the question of whether a single physical exercise improves the lipid profile. A decrease in LDL-C and TG levels after an ultramarathon run [48] and an increase in TG levels during such a run [24] as well as an increase in TG levels after a marathon [42] have been observed.

The increase in HDL-C concentration before and after the fasting intervention, caused by an exercise test, suggests that a single physical effort may be an effective tool against atherosclerosis [43].

Our research showed that a single exercise altered the lipid profile, and an 8-day water-only fast modified the resulting changes.

Changes in carbohydrate metabolism after fasting and exercise

Reductions in the normal values of insulin, glucose and HOMA-IR under the conditions of simultaneous exposure to 8 days of water-only fasting and physical effort should be considered as a favorable response and attributed mainly to the fasting intervention.

Decreased glucose concentration after 8 days of water-only fasting is an expression of reduced efficiency of gluconeogenesis, the peak of which falls on the 4th-5th day of fasting [30]. Decreased glucose concentration has also been demonstrated in a large cohort of 1,422 people using restricted fasting for 4–21 days [47] and was considered as one of the factors to reduce the risk of CVD [45]. Also lower insulin concentrations generated by fasting intervention in the post-exercise period are a positive effect of the body's adaptation to these conditions [44].

A similar modifying effect of the fasting intervention occurred in terms of changes in the HOMA-IR index. Correct values of insulin concentration and HOMA-IR index, and their reduction during fasting intervention in

our studies, indicate adequate glycemic control [29, 35]. These facts are confirmed by the correct values of the TG/HDL-C ratio, which is also a recognized indicator of insulin resistance [27]. However, the lack of changes in the TG/HDL-C ratio, and even a tendency for it to increase, caused by a fasting intervention, makes it necessary to take into account the observation that a few days of complete fasting can generate insulin resistance [11]. The results of our study, however, do not clearly indicate the possibility of fasting-induced insulin resistance.

It should be noted that moderate and high-intensity physical exercise also play an important role in glycemic control [21]. However, our study did not show any changes in glucose, insulin and HOMA-IR values recorded 3 minutes after the end of exercise, although improvements in insulin sensitivity and glucose tolerance were previously observed in a few hours of post-exercise restitution in healthy subjects [34].

To sum up, we observed that 8 days of water-only fasting improved carbohydrate metabolism and there were no significant changes in this regard during a single exercise of maximum intensity.

Fasting impact on body mass

Body weight reduction is associated with increased use of fats during fasting [30], which was reflected in our research by a significant, over 11.00% reduction in the weight of this tissue. It was also noted that the amount of weight reduction was associated with insulin resistance. Cornier et al. [6] found that a greater reduction in body weight occurred in people with normal insulin resistance, using a hypoenergetic diet with a high content of carbohydrates. Therefore, it can be concluded that the limited amount of carbohydrates in fasting may be a factor slowing down the amount of weight loss in healthy people. It was also observed that body weight reduction occurred with a decrease in LDL-C concentration [15]. However, in our study, this effect did not occur because, despite significant weight loss during the 8 days of water-only fasting, LDL-C levels remained unchanged.

In parallel with the reduction in fat content during the 8 days of water-only fasting, there was a reduction in absolute FFM values. The percentage of FFM showed a significant increase after the fasting intervention, which indicates its saving during this period due to the stabilization of muscle mass containing significant water and protein reserves [19, 30].

The final, positive effect resulting from the reduction of body weight was the reduction of BMI, which before the start of the study exceeded reference values, and after 8 days of water-only fasting reached the level recommended for people with normal body weight. However, maintaining complete fasting, although it is an effective way to improve health, cannot be continued for a longer period of time. A more effective health prophylaxis seems to be caloric restriction, which can be applied even for several months [18].

Changes in the cardiovascular system after fasting and exercise

The combination of 8 days of water-only fasting with one-time exercise in our study led to significant changes in HR, SBP and DBP. These changes were mainly caused by the exercise test of maximum intensity, during which the sympathetic nervous system was stimulated [26]. The maximum heart rates achieved during the stress test indicated that the effort performed both before and after the starvation intervention was maximal. However, the maximum aerobic power achieved was lower and the duration of the exercise test was shorter after the fasting intervention, which is attributed to the limited availability of carbohydrates [10]. It was found that although the resting SBP values before the fasting intervention in our study were within the reference limits, in 2 cases the pressure under maximum aerobic power load exceeded the dangerous limit of 220 mm Hg, both before and after the application of the fasting intervention. These changes indicate the possibility of latent hypertension in these people [2] and the ineffective impact of fasting intervention on its reduction. However, the analysis of the entire group of men studied showed that despite the lack of significant changes in the lipid profile, 8 days of water-only fasting had a significant effect on the reduction of SBP at rest, and also stimulated an increased tendency in this direction during exercise load. The reason for the decrease in systolic and diastolic blood pressure in other studies was considered to be an increase in the activity of the parasympathetic nervous system caused by partial fasting [47].

This suggestion also seems to be in line with previous studies that showed that parasympathetic activity was negatively correlated with decreased glucose during overnight fasting [22]. It should be mentioned here that in our study, glucose concentration after 8 days of water-only fasting was also decreased, which, according to the above suggestions, may indicate parasympathetic stimulation reducing SBP.

Limitations of the study

The conducted study has several limitations. 1) Men were not selected randomly for the research, but as a result of their own interest in the effects of fasting on the body, which may affect the probability of representativeness. 2) The 8-day water-only fast was a difficult attempt to survive, affecting the small number of men in the study. 3) The results obtained mainly after fasting intervention were compared to the reference values for healthy people who were in a state of physiological nutrition. 4) For the above reasons, the conclusions drawn have limited

application value and cannot be extended to a larger population.

Conclusions

Since the use of 8 days of water-only fasting and one-time exercise is associated with the depletion of carbohydrate stores and increased use of fats in the body, changes in the lipid profile and carbohydrate metabolism seem to follow these trends. The simultaneous influence of both of these factors significantly changed the concentrations of TC, HDL-C, nHDL-C, LDL-C, TG, insulin, glucose, β-HB, HOMA-IR, as well as such indicators of cardiovascular function as HR, SBP, DBP. However, each of these factors had different effects on the body. Eight days of water-only fasting had a prophylactic effect on insulin resistance, improved insulin sensitivity, intensified the ketogenesis process, and led to positive somatic changes, while the exercise test caused significant changes in the lipid profile and cardiovascular function. In conclusion, we found that the combined effect of the fasting intervention and the exercise test led to a more comprehensive improvement in health indicators of the examined men than the independent effect of each of these factors.

Conflict of interest: Authors state no conflict of interest.

References

1. Akhtar P., Kazmi A., Sharma T., Sharma A. (2020) Effects of Ramadan fasting on serum lipid profile. *J. Family Med. Prim. Care,* 9(5): 2337-2341. DOI: 10.4103/jfmpc.jfmpc_550_19.
2. American Thoracic Society, American College of Chest Physicians. (2003) AST/ACCP statement on cardiopulmonary exercise testing. *Am. J. Respir. Crid. Care Med.,* 167(2): 211-277. DOI: 10.1164/rccm.167.2.211.
3. Arnason T.G., Bowen M.W., Mansell K.D. (2017) Effects of intermittent fasting on health markers in those with type 2 diabetes: a pilot study. *World J. Diabetes*, 8(4): 154-164. DOI: 10.4239/wjd.v8.i4.154.
4. Azevedo F.R., Ikeoka D., Caramelli B. (2013) Effects of intermittent fasting on metabolism in men. *Rev. Assoc. Med. Bras.,* 59(2): 167-173. DOI: 10.1016/j.ramb.2012.09.003.
5. Bhutani S., Klempel M.C., Kroeger C.M., Trepanowski J.F., Varady K.A. (2013) Alternate day fasting and endurance exercise combine to reduce body weight and favorably alter plasma lipids in obese humans. *Obesity* (Silver Spring), 21(7): 1370-1379. DOI: 10.1002/oby.20353.
6. Cornier M.A., Donahoo W.T., Pereira R., Gurevich I., Westergren R., Enerback S., Eckel P.J., Goalstone M.L., Hill J.O., Eckel R.H., Draznin B. (2005) Insulin sensitivity determines the effectiveness of dietary macronutrient composition on weight loss in obese women. *Obes. Res*., 13(4): 703-709. DOI: 10.1038/oby.2005.79.
7. Dobiásová M. (2014) Atherogenic index of plasma [log(triglycerides/HDL-cholesterol)]: theoretical and practical implications. *Clin. Chem*., 50(7): 1113-1115. DOI: 10.1373/ clinchem.2004.033175.
8. Dobiásová M., Frohlich J., Sedová M., Cheung M.C., Brown B.G. (2011) Cholesterol esterification and atherogenic index of plasma correlate with lipoprotein size and findings on coronary angiography. *J. Lipid Res*., 52(3): 566-571. DOI: 10.1194/jlr.P011668.
9. Elliott B., Mina M., Ferrier C. (2016) Complete and Voluntary Starvation of 50 days. *Clin. Med. Insights Case Rep*., 9: 67-70. DOI: 10.4137/CCRep.S39776.
10. Ferreira G.A., Felippe L.C., Silva R.L.S., Bertuzzi R., De Oliveira F.R., Pires F.O., Lima-Silva A.E. (2018) Effect of pre-exercise carbohydrate availability on fat oxidation and energy expenditure after a high-intensity exercise. *Braz. J. Med. Biol. Res.*, 51(5): e6964. DOI: 10.1590/1414-431X20186964.
11. Frank P., Katz A., Andersson E., Sahlin K. (2013) Acute exercise reverses starvation-mediated insulin resistance in humans. *Am. J. Physiol. Endocrinol. Metab.,* 304(4): E436–E443. DOI: 10.1152/ajpendo.00416.2012.
12. Friedewald W.T., Levy R.I., Fredrickson D.S. (1972) Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin. Chem.,* 18(6): 499-502.
13. Frøsig Ch., Richter E.A. (2009) Improved Insulin Sensitivity After Exercise: Focus on Insulin Signaling. *Obesity* (Silver Spring), 17(3): 15-20. DOI: 10.1038/oby.2009.383.
14. Gabel K., Hoddy K.K., Haggerty N., Song J., Kroeger C.M., Trepanowski J.F., Panda S., Varady K.A. (2018) Effects of 8-hour time restricted feeding on body weight and metabolic disease risk factors in obese adults: a pilot study. *J. Nutr. Health. Aging,* 4(4): 345-353. DOI: 10.3233/NHA-170036.
15. Goldberg A.C., Hopkins P.N., Toth P.P., Ballantyne C.M., Rader D.J., Robinson J.G., Daniels S.R., Gidding S.S., de Ferranti S.D., Ito M.K., McGowan M.P., Moriarty P.M., Cromwell W.C., Ross J.L., Ziajka P.E., National Lipid Association Expert Panel on Familial Hypercholesterolemia. (2011) Familial hypercholesterolemia: screening, diagnosis and management of pediatric and adult patients: clinical guidance from the National Lipid Association Expert Panel on familial hypercholesterolemia. *J. Clin. Lipidol*., 5(3): 1-8. DOI: 10.1016/j.jacl.2011.04.003.
16. Harvie M., Wright C., Pegington M., McMullan D., Mitchell E., Martin B., Cutler R.G., Evans G., Whiteside S.,

Maudsley S., Camandola S., Wang R., Carlson O.D., Egan J.M., Mattson M.P., Howell A. (2013) The effect of intermittent energy and carbohydrate restriction v. daily energy restriction on weight loss and metabolic disease risk markers in overweight women. *Br. J. Nutr.,* 110(8): 1534-1547. DOI: 10.1017/S0007114513000792.

17. Harvie M.N., Pegington M., Mattson M.P., Frystyk J., Dillon B., Evans G., Cuzick J., Jebb S.A., Martin B., Cutler R.G., Son T.G., Maudsley S., Carlson O.D., Egan J.M., Flyvbjerg A., Howell A. (2011) The effects of intermittent or continuous energy restriction on weight loss and metabolic disease risk markers: a randomized trial in young overweight women. *Int. J. Obes.,* 35(5): 714-727. DOI: 10.1038/ijo.2010.171.
18. Hołowko J., Michalczyk M.M., Zając A., Czerwinska-Rogowska M., Ryterska K., Banaszczak M., Jakubczyk K., Stachowska E. (2019) Six weeks of calorie restriction improves body composition and lipid pro – file in obese and overweight former athletes. *Nutrients,* 11(7): 1461. DOI: 10.3390/nu11071461.
19. Hori T., Nakamura S., Yamagami H., Yasui S., Hosoki M., Hara T., Mitsui Y., Masuda S., Kurahashi K., Yoshida S., Harada T., Kuroda A., Otoda T., Yuasa T., Endo I., Matsuhisa M., Abe M., Aihara K.I. (2023) Phase angle and extracellular water-to-total body water ratio estimated by bioelectrical impedance analysis are associated with levels of hemoglobin and hematocrit in patients with diabetes. *Heliyon,* 9(4): e14724. DOI: 10.1016/j.heliyon.2023.e14724.
20. Ivy J.L., Holloszy J.O. (1981) Persistent increase in glucose uptake by rat skeletal muscle following exercise. *Am. J. Physiol.,* 241(5): C200–C203. DOI: 10.1152/ajpcell.1981.241.5.C200.
21. Jelleyman C., Yates T., O'Donovan G., Gray L., King J.A., Khunti K., Davies M.J. (2015) The effects of high-intensity interval training on glucose regulation and insulin resistance: A meta-analysis. *Obes. Rev*., 16(11): 942-961. DOI: 10.1111/obr.12317.
22. Kamata N., Tanaka K., Morita S., Tagaya H., Kawashima M., SHichiri M., Miyaoka H. (2011) Relationship between Autonomic Nervous System Activity during Sleep and Fasting Glucose in Japanese Workers. *Ind. Health,* 49(4): 427-433. DOI: 10.2486/indhealth.ms1257.
23. Kimm H., Lee S.W., Lee H.S., Shim K.W., Cho C.Y., Yun J.E., Jee S.H. (2010) Associations between lipid measures and metabolic syndrome, insulin resistance and adiponectin: usefulness of lipid ratios in Korean men and women. *Circ. J.,* 74(5): 931-937. DOI: 10.1253/circj.CJ-09-0571.
24. Kłapcińska B., Waśkiewicz Z., Chrapusta S.J., Sadowska-Krępa E., Czuba M., Langfort J. (2013) Metabolic responses to a 48-h ultra-marathon run in middle-aged male amateur runners. *Eur. J. Appl. Physiol*., 113(11): 2781-2793. DOI: 10.1007/s00421-013-2714-8.
25. Letkiewicz S., Pilis K., Ślęzak A., Pilis A., Pilis W., Żychowska M., Langfort J. (2020) Eight days of water-only fasting promotes favorable changes in the functioning of the urogenital system of middle-aged healthy men. *Nutrients*, 13(1): 113. DOI: 10.3390/nu13010113.
26. Lima-Silva A.E, Bertuzzi R.C., Fronchetti L., Gevaerd M.S., De-Oliveira F.R. (2010) A low carbohydrate diets affects autonomic modulation during heavy but not moderate exercise. *Eur. J. Appl. Physiol*., 108(6): 1133-1140. DOI: 10.1007/s00421-009-1329-6.
27. McLaughlin T., Reaven G., Abbasi F., Lamendola C., Saad M., Waters D., Simon J., Krauss R.M. (2005) Is there a simple way to identify insulin-resistant individuals at increased risk of cardiovascular disease? *Am. J. Cardiol*., 96(3): 399-404. DOI: 10.1016/j.amjcard.2005.03.085.
28. Mrakic-Sposta S., Gussoni M., Moretti S., Pratali L., Giardini G., Tacchini P., Dellanoce C., Tonacci A., Mastorci F., Borghini A., Montorsi M., Vezzoli A. (2015) Effects of Mountain Ultra-Marathon Running on ROS Production and Oxidative Damage by Micro-Invasive Analytic Techniques. *PLoS One,* 10(11): e0141780. DOI: 10.1371/journal.pone.0141780.
29. Nielsen J.V., Joensson E. (2006) Low-carbohydrate diet in 2 type diabetes. Stable improvement of body weight and glicemic control during 22 months of follow-up. *Nutr. Metab*. (Lond.), 3: 22. DOI: 10.1186/1743-7075-3-22.
30. Palmer B.F., Clegg D.J. (2021) Starvation Ketosis and the Kidney. *Am. J. Nephrol.,* 52(6): 467-478. DOI: 10.1159/000517305.
31. Parr E.B., Heilbronn L.K., Hawley J.A. (2020) A Time to Eat and a Time to Exercise. *Exerc. Sport Sci. Rev.* 48(1): 4-10. DOI: 10.1249/JES.0000000000000207.
32. Pilis K., Pilis A., Stec K., Pilis W., Langfort J., Letkiewicz S., Michalski C., Czuba M., Zych M., Chalimoniuk M. (2018) Three-year chronic consumption low-carbohydrate diet impairs exercise performance and has a small unfavorable effect on lipid profile in middle-aged men. *Nutrients,* 10(12): 1914. DOI: 10.3390/nu10121914.
33. Rajappa M., Sridhar M.G., Balachander J., Sethuraman K.R., Rajendiran K.S. (2014) Lipoprotein ratios as surrogate markers for insulin resistance in South Indians with normoglycemic nondiabetic acute coronary syndrome. *ISRN Endocrinol.,* 2014: 981524. DOI: 10.1155/2014/981524.
34. Richter E.A., Garetto L.P., Goodman M.N., Ruderman N.B. (1984) Enhanced muscle glucose metabolism after exercise: modulation by local factors. *Am. J. Physiol.,* 246: E476–E482. DOI: 10.1152/ajpendo.1984.246.6.E476.
35. Sadowska-Krępa E., Gdańska A., Pridalova M., Rozpara M., Grabara M. (2022) The effect of calorie restriction on the anthropometric parameters, HOMA-IR index, and lipid profile of female office workers with

overweight and obesity: a preliminary study. *Int. J. Occupat. Med. Environ*. *Health*, 35(6): 1-14. DOI: 10.13075/ijomeh.1896.01963.
36. Sales M.M., Sousa C.V., Aguiar S.S., Knechtle B., Nikolaidis P.T., Alves P.M., Simões H.G. (2019) An integrative perspective of the anaerobic threshold. *Physiol. Behav*., 205: 29-32. DOI: 10.1016/j.physbeh.2017.12.015.
37. Santos O.H., Macedo R.C.O. (2018) Impact of intermittent fasting on the lipid profile: Assessment associated with diet and weight loss. *Clin. Nutr. ESPEN,* 24: 14-21. DOI: 10.1016/j.clnesp.2018.01.002.
38. Stec K. (2012) Dynamic Suryanamaskar – Sun Salutations. Swami Vivekananda Yoga Prakashana, Bangalore.
39. Steinhauser M.L., Olenchock B.A., O'Keefe J., Lun M., Pierce K.A., Lee H., Pantano L., Klibanski A., Shulman G.I., Clish C.B., Fazeli P.K. (2018) The circulating metabolome of human starvation. *J. CI. Insight*, 3(16): e121434. DOI: 10.1172/jci.insight.121434.
40. Teng N.I.M.F., Shahar S., Manaf Z.A., Das S.K., Taha C.S.C., Ngah W.Z.W. (2011) Efficacy of fasting calorie restriction on quality of life among aging men. *Physiol Behav.,* 104(5): 1059-1064. DOI: 10.1016/j.physbeh.2011.07.007.
41. Trepanowski J.F., Kroeger C.M., Barnosky A., Klempel M., Bhutani S., Hoddy K.K., Rood J., Ravussin E., Varady K.A. (2018) Effects of alternate-day fasting or daily calorie restriction on body composition, fat distribution, and circulating adipokines: secondary analysis of a randomized controlled trial. *Clin. Nutr.* 37(6): 1871-1878. DOI: 10.1016/j.clnu.2017.11.018.
42. Vaisberg M., Bachi A.L., Latrilha C., Dioguardi G.S., Bydlowski S.P., Maranhao R.C. (2012) Lipid transfer to HDL is higher in marathon runners than in sedentary subjects, but is acutely inhibited during the run. *Lipids*, 47(7): 679-686. DOI: 10.1007/s11745-012-3685-y.
43. Välimäki I.A., Vuorimaa T., Ahotupa M., Vasankari T.J. (2016) Strenuous physical exercise accelerates the lipid peroxide clearing transport by HDL. *Eur. J. Appl. Physiol*., 116(9): 1683-1691. DOI: 10.1007/s00421-016-3422-y.
44. Vink R.G., Roumans N.J., Čajlaković M., Cleutjens J.P.M., Boekschoten M.V., Fazelzadeh P., Vogel M.A.A., Blaak E.E., Mariman E.C., van Baak M.A., Goossens G.H. (2017) Diet-induced weight loss decreases adipose tissue oxygen tension with parallel changes in adipose tissue phenotype and insulin sensitivity in overweight humans. *Int. J. Obes*., 41(5): 722-728. DOI: 10.1038/ijo.2017.38.
45. Volek J.S., Phinney S.D., Forsythe C.E., Quann E.E., Wood R.J., Puglisi M.J., Kraemer W.J., Bibus D.M., Fernandez M.L., Feinman R.D. (2009) Carbohydrate restriction has a more favorable impact on the metabolic syndrome than a low fat diet. *Lipids*, 44(4): 297-309. DOI: 10.1007/s11745-008-3274-2.
46. Wallace T.M., Matthews D.R. (2002) The assessment insulin resistance in man. *Diabet. Med*., 19(7): 527-534. DOI: 10.1046/j.1464-5491.2002.00745.x.
47. Wilhelmi de Toledo F., Grundler F., Bergouignan A., Drinda S., Michalsen A. (2019) Safety, health improvement and well-being during a 4 to 21-day fasting period in an observational study including 1422 subjects. *PLoS One*, 14(1): e0209353. DOI: 10.1371/journal.pone.0209353.
48. Wu H.J., Chen K.T., Shee B.W., Chang H.C., Huang Y.J., Yang R.S. (2004) Effects of 24 h ultra-marathon on biochemical and hematological parameters. *World J. Gastroenterol*., 10(18): 2711-2714. DOI: 10.3748/wjg.v10.i18.2711.
49. You J., Wang Z., Lu G., Chen Z. (2020) Association between the non-high-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio and the risk of coronary artery disease. *Biomed. Res. Int.,* 2020: 7146028. DOI: 10.1155/2020/7146028.
50. Zouhal H., Saeidi A., Salhi A., Li H., Essop M.F., Laher I., Rhibi F., Amani-Shalamzari S., Ben Abderrahman A. (2020) Exercise Training and Fasting: Current Insights. *Open Access J. Sports Med.,* 11: 1-28. DOI: 10.2147/OAJSM.S224919.

Received 14.08.2023
Accepted 17.10.2023

© University of Physical Education, Warsaw, Poland