

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

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Abstract

Objectives: This study evaluates the effect of a 3-month calorie restriction (CR) without snacking on the anthropometric parameters, Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), and lipid profiles of female office workers with overweight or obesity, whose physical activity was limited during the COVID-19 pandemic lockdown. **Material and Methods:** Forty-eight women aged 20–38 years (28.9 ± 5.24) with low physical activity levels were divided into a non-snacking (NS) group ($N = 21$) and a snacking (S) group ($N = 27$) prior to the dietary intervention. Their daily energy intake during the intervention was lowered by 30% compared with the baseline level, and the proportion of polyunsaturated fatty acids and fiber in their diet was increased (to >30 g/day). The proportion of saturated fatty acids and simple carbohydrates was also reduced. The study participants were assessed at the baseline and post-intervention for anthropometric variables (body weight, body fat percentage BMI, waist circumference, hip circumference, waist-to-hip ratio) and the concentrations of insulin, total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C). Moreover, the values for HOMA-IR, the atherogenic index of plasma (AIP), and the ratios of TC/HDL-C, TG/HDL-C, and LDL-C/HDL-C were calculated. **Results:** All anthropometric parameter values obtained post-intervention were lower than the baseline in both groups. The serum insulin concentration and HOMA-IR decreased respectively by an average of 6% and 25% in the NS group and 37% and 45% in the S group. The lipid profiles of all participants improved significantly, with the LDL-C concentration showing a more promising trend in the S group (decrease by 27%) than in the NS group (17%). **Conclusions:** The study showed that CR improved the anthropometric parameters, HOMA-IR index, and lipid profiles of all participants. *Int J Occup Med Environ Health.* 2022;35(6):693–706

Key words:

insulin resistance, lipid profile, reduction diet, snacking, coronavirus pandemic, low physical activity level

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INTRODUCTION

Although peripheral insulin resistance (IR) and hyperinsulinemia are more likely to develop in people with obesity, IR is also diagnosed in individuals who are not obese [1]. They, too, are prone to metabolic syndrome, but because their body mass is in the normal range (BMI of 18.5–24.9), they are usually not treated until some health problems arise [2]. Insulin resistance leads to the development of metabolic disturbances in various tissues. There is a decrease in glucose uptake and consumption by oxidation as well as impaired glucose storage as glycogen in the skeletal muscle. In adipose tissue, insulin has no inhibitory effect on lipolysis; IR is the main pathogenic factor of type 2 diabetes mellitus. The decreased insulin sensitivity of the tissues is compensated by hyperinsulinemia, thanks to which some patients with IR do not develop type 2 diabetes for many years, instead developing other elements of metabolic syndrome, i.e., abdominal obesity, hypertension, and atherogenic dyslipidemia [1,3].

Determining which diets are the most effective in improving glucose/insulin homeostasis and managing obesity is a matter of ongoing debate. Among the obesity monitoring and weight management strategies that have been proven to be effective and are increasingly used in recent years are low-carbohydrate diets [4], the low-calorie ketogenic diet [5], intermittent fasting (IF) [6], and personalized nutritional programs based on biological evidence of differential responses to foods/nutrients depending on the phenotypical traits and genotype of an individual [7]. With regard to the more traditional diets, the Mediterranean diet [8,9], DASH [10], and low-calorie, nutrient-modified diets [11] are recommended for people with obesity. These diets emphasize calorie restriction, high nutrition density, low energy value, and foods with a high satiety index [12]. Some guidelines on obesity management advise eating at regular intervals (4–5 times/day, every 3 h) to lower the demand

for energy intake, stimulate thermogenesis, and improve the rhythm of insulin secretion [13]. It is argued that around 40–60% of daily calories should come from carbohydrates with a low glycemic index and load [14], 30% from fats, and not more than 10% from animal fats [15]. Some authors recommend consuming at least 0.85 g of high biological value proteins per kg of body mass and ca. 35–45 g/day of fiber-rich foods, eating <5 g/day of salt, and having the last meal no later than 3–4 h before bedtime [16–18].

In most cases, the distinction between a “meal” and a “snack” is made based on when they are eaten during the day and/or their nutrient composition. A meal is commonly defined as one of the main eating occasions of the day, whereas a snack is usually understood as food consumed between the main meals and additionally boosting postprandial glycemia and the insulin response [19,20]. Abstaining from snacks therefore helps maintain a negative caloric balance and normalizes the blood glucose level [21].

According to one approach, an effective diet is one that reduces the initial body mass by 7–10% over a period of 3 months [22]. With regard to people with overweight and obesity, this reduction can be achieved by reducing their daily calorie intake by around 500–1000 kcal below their total daily energy requirement [23,24]. Fast weight-loss plans are advised against as they carry the risk of lean body mass loss, nutritional deficiency disorders, and lowering the resting metabolic rate [25]. One of the main problems affecting the effectiveness of calorie restriction diets is snacking, which makes it more difficult for the dieting person to achieve a healthy BMI [22].

Despite the evidence that a combination of calorie restriction (CR) and physical activity (PA) is the most effective in treating overweight and obesity, changing the eating habits and increasing PA at the same time may not be possible for many practical reasons [26]. For instance, many female office workers have little time to exercise, having

to take care of their work duties, children, and household chores. Long periods of physical isolation imposed by the current COVID-19 pandemic also discourage people from engaging in physical activity [24,27].

As lowering the dietary energy intake is known to reduce body mass and improve glycemic control and lipid management [28], this study set out to assess the effect of a 3-month CR on the anthropometric parameters, Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), and lipid profiles of female office workers with overweight and obesity who had or had not snacked before a dietary intervention. A hypothesis was formulated that having the participants reduce their calorie intake and have meals at regular intervals would protect them from the adverse effects of hyperglycemia and hyperinsulinemia and would help reduce their body mass while improving their insulin concentration levels and lipid profiles.

MATERIAL AND METHODS

Participants

The study involved female office workers with overweight or obesity, who were forced to reduce their physical activity as a result of the COVID-19 pandemic lockdown. All participants were recruited when visiting a dietitian for advice. Of the 65 women invited, 48 (ages 20–38 years old; $2 \text{ M} \pm \text{SD } 8.9 \pm 5.24$) met the enrollment criteria (good health, female gender, low physical activity, and overweight or obesity) and were enrolled. Women who smoked or had type 2 diabetes, arterial hypertension, congenital insulin resistance, hypothyroidism, polycystic ovary syndrome, or other hormonal disorders, or who were moderately or highly active, were excluded from the study.

Participants were divided into those who did not have the habit of snacking between main meals (NS group, $N = 21$) and those who had 1–5 snacks/day (i.e., fruit, yogurt, nuts and sweets, sweet drinks, chips, cookies, etc.) before the diet intervention, contributing on average 410.93 ± 228.38 kcal (S group, $N = 27$).

Methods and procedures

The study protocol conformed to the ethical guidelines of the World Medical Association Declaration of Helsinki and was approved by the Ethics Committee of the Jerzy Kukuczka Academy of Physical Education in Katowice (Poland). All participants were familiarized with its protocol and purpose and gave their written consent to participate in it. They were also advised that they could withdraw from the study at any time.

The daily energy intake of participants was estimated from the food diaries they received to record the weight and number of meals they had each day for 7 days prior to the intervention [29].

The study was conducted in September–November 2020, when the participants were physically less active having to stay and work from home due to the pandemic and lockdown. In order to determine their actual PA levels, they were asked by the dietician during one of the first control meetings to fill in the *Seven-Day Physical Activity Recall* questionnaire (SDPAR).

Anthropometric measurements

The anthropometric parameters were measured before and after the intervention in the morning hours after an overnight fast. Body height was measured only once, at the baseline. Body mass and body fat percentage (BFP) were determined using an InBody[®]570 Multifrequency Bioelectrical Impedance Analyzer (Biospace Co., Ltd., Seoul, Korea). Waist circumferences (WC) were measured at the midpoint between the lowest rib and the iliac crest and hip circumferences (HC) around the largest part of the buttocks to the nearest 0.5 cm in a standing position.

Physical activity

The participants' weekly energy expenditure was assessed and converted into kilocalories by means of SDPAR, where a score of 10 metabolic equivalent of task (MET) is equivalent to highly vigorous PA, 6 METs to vigorous PA, and 4 METs

to moderate PA [30]. The physical activity of each participant was compared with the American College of Sports Medicine (ACSM) recommendations, according to which adults aged 18–64 years should engage in moderate-intensity aerobic PA for at least 30 min on 5 days each week or in vigorous-intensity aerobic PA for at least 20 min on 3 days [31].

Dietary intervention

Individual dietary plans (allowing for participants' preferred meal times and foods) were prepared by a dietician based on the participants' food diaries and interviews using the Diet Perfect website [32]. Dietary nutrient ratios were calculated as per the revised nutritional norms for Poland's population [17]. The focus of the plans was on reducing the daily intake of calories (by 30% compared with the baseline level), fatty acids, and simple carbohydrates, while increasing the proportion of poly- and monosaturated fatty acids and dietary fiber (>30 g/day). Participants were advised to have 4–5 meals/day at regular intervals, to eat the last meal 3–4 h before bedtime, and to abstain from snacking. However, they were free to drink water, fruit and herbal teas, or black tea and black coffee without sugar between meals *ad libitum*.

The participants' compliance with the dietary regimen was ensured by checking their food diaries during the weekly, obligatory meetings with the dietician, which were conducted in strict conformity with the COVID-19 safety rules. As part of the meetings, the participants' body mass and body composition were also assessed.

Biochemical analysis

Fasting blood samples were taken at the baseline and post-intervention between 8:00 and 10:00 a.m., also after an overnight fast. Blood serum was separated in the usual manner and stored frozen at -80°C until analysis. The serum insulin levels were determined by the immunoradiometric method (Insulin IRMA IM3210, sensitivity 2.0 mIU/ml, Immunotech SA, France), and insu-

lin sensitivity using the homeostatic model assessment (HOMA) as described by Matthews [33].

The concentrations of serum total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), and glucose were measured using enzymatic assays and commercially available diagnostic kits (Randox UK, Cat. No. CH 200, CH 203, TR 1697, and GL 2623, respectively). The intra- and inter-assay coefficients of variation (CV) were 1.98–4.28% for TC, 1.10–4.01% for HDL-C, and 2.69–4.57% for TG; the CV ranges for glucose were not stated by the kit manufacturer. The concentrations of low-density lipoprotein cholesterol (LDL-C) were calculated from TC, HDL-C, and TG as per Friedewald's formula [34]. The risk for vascular diseases in both groups was estimated based on the lipid ratios (TC/HDL-C, LDL-C/HDL-C, TG/HDL-C) and the atherogenic index of plasma where TG and HDL-C are expressed as molar concentrations [35]:

$$\text{AIP} = \log_{10}(\text{TG}/\text{HDL-C}) \quad (1)$$

where:

AIP – atherogenic index of plasma,

HDL-C – high-density lipoprotein cholesterol,

TG – triglycerides.

The formula for calculating the HOMA-IR was the following:

$$\text{HOMA-IR} = \text{glucose (mmol/l)} \times \text{insulin (mIU/l)} / 22.5. \quad (2)$$

Following the instructions of the assay manufacturers, biochemical analyses were performed by a laboratory certified as conforming to PN-EN ISO 9001:2015.

Statistical analysis

The data is presented as mean values (M) and standard deviations (SD). The normality of distributions and homogeneity of variance were tested by the Shapiro-Wilk

test and Levene's test, respectively. Between-group differences in physical activity and pre-intervention diet were analyzed using the Mann-Whitney test. The significance of the differences between the anthropometric variables and the biochemical variables (lipid, glucose, and insulin concentrations) measured before and after the intervention was assessed by the paired-samples t-test when a variable had a normal distribution; otherwise, the Wilcoxon signed-rank test was used. The effect size was evaluated using the Cohen's *d* (dc, the paired-samples t-test) (the paired-samples t-test):

- 0.2 to <0.3 – small effect,
- 0.5 to <0.8 – medium effect,
- ≥ 0.8 to large effect [36],

as well as the *r* index (the Wilcoxon signed-rank test):

- 0.1 to <0.3 – small effect,
- 0.3 to <0.5 – medium effect,
- ≥ 0.5 to large effect [37].

The level of significance in all tests was set as $\alpha = 0.05$. All statistical procedures were performed in IBM SPSS Statistics 26.0 (IBM Corporation, Armonk, NY, USA).

RESULTS

Baseline measurements

The mean height of the participants was 166.2 ± 8.73 cm in the NS group and 164.9 ± 6.2 cm in the S group. Body mass index measurements showed that 35 participants were overweight (15 and 20 in the NS and S groups, respectively) and 13 were obese (5 and 8 in the NS and S groups, respectively). Before the intervention, women in the S group consumed significantly ($p < 0.05$) more calories, protein, and dietary fiber compared with the NS group. The diets of the women in both groups and their eating habits before the intervention are characterized in Table 1.

Changes following calorie restriction

The intervention diet was the same in both groups regarding total energy content and particular components (Table 1).

The PA levels determined from the SDPAR did not significantly differentiate the snacking group from the non-snacking one (Table 2). High-vigorous PA was not reported by either group. The weekly duration of moderate physical activity (DMPA) and duration of vigorous physical activity (DVPA) of the studied women were insufficient to meet the the American College of Sports Medicine (ACSM) recommendations [31]. The weekly energy expenditure of all women due to moderate or vigorous physical activity (EEM-VPA) was estimated at around 500 kcal.

In both groups, significant decreases ($p < 0.001$) in the participants' body mass, BMI, WC, HC, and F were recorded at month 3; in the snacking group, a significantly lower WHR ($p < 0.05$) was also observed (Table 3). In 21 women (7 in the NS group and 14 in the S group), the post-intervention BMI was < 25 , and in 9 women (3 in the NS group and 6 in the S group), it was < 30 .

The glucose concentrations, HOMA-IR index, atherogenic index of plasma (AIP), and all lipid profile markers measured after the intervention were significantly lower ($p < 0.001$) than at the baseline in both groups. In the S group, a significant decrease ($p < 0.001$) in the insulin concentration was also noted (Table 3).

DISCUSSION

The COVID-19 pandemic, with its lockdowns, working from home, and concerns of contracting coronavirus, is conducive to overeating while discouraging physical activity [38,39]. In these circumstances, calorie restriction diets may prove an effective way to help people maintain a healthy body mass and lipid profile [40–42]. The main aim of this study set out to determine the effect of a 3-month CR (without snacking between meals) on the anthropometric parameters, HOMA-IR index, and lipid profiles of 48 female office workers with BMIs exceeding the normal range by as much as 12%. The study participants were divided into 2 groups: one consisting of women who did not snack before the intervention, and

Table 1. Diet and meal frequency of the studied women before and during intervention, the study was conducted at the dietician's office in Rybnik and the Jerzy Kukuczka Academy of Physical Education in Katowice, September–November 2020

Variable	Participants (N = 48) (M±SD)					
	before intervention			during intervention ^a		
	total	non-snacking group (N = 21)	snacking group (N = 27)	total	non-snacking group (N = 21)	snacking group (N = 27)
Total energy intake [kcal]	2246.88±354.75	2116.71±311.17	2348.11±358.72*	1564.33±99.16	1577.37±107.89	1554.19±92.62
Water [g]	964.67±254.25	986.71±215.39	947.52±283.68	909.13±74.51	923.01±74.94	898.34±73.75
Protein [g]	67.26±19.38	62.24±19.15	71.17±18.99*	84.81±8.39	84.10±9.72	85.37±7.34
Energy from protein [%]	11.94±2.68	11.67±2.56	12.15±2.80	21.64±1.71	21.34±1.67	21.86±1.74
Fat [g]	85.66±11.17	86.40±13.67	85.08±9.00	48.02±8.46	49.18±7.60	47.11±9.10
Energy from fat [%]	33.31±6.03	32.14±5.93	34.22±6.06	27.66±4.74	28.36±4.62	27.12±4.85
Carbohydrates [g]	305.82±61.90	294.33±46.64	314.76±71.16	197.40±26.16	194.59±27.27	199.58±25.56
Energy from carbohydrates [%]	54.48±6.64	55.95±6.61	53.33±6.56	50.70±4.41	50.30±4.40	51.01±4.48
Simple carbohydrates [g]	13.73±8.92	12.87±6.70	14.41±10.40	2.25±1.56	2.36±1.61	2.17±1.54
Dietary fiber [g]	26.83±6.20	24.60±5.90	28.57±5.96*	34.73±2.83	34.35±2.88	35.02±2.82
Fats [g]						
unsaturated	12.35±4.79	12.43±4.85	12.26±4.83	15.48±2.63	15.14±2.93	15.82±2.38
monounsaturated	7.19±0.98	7.61±1.73	6.76±1.90	8.76±1.02	8.64±1.44	8.87±1.53
polyunsaturated	5.16±1.34	4.82±1.13	5.50±1.36	6.73±0.28	6.50±0.57	6.95±0.71
Total cholesterol [g]	623.65±138.37	595.19±122.56	645.78±147.96	323.18±21.23	322.87±17.40	323.42±24.12
Meals [n]	4.44±0.77	4.23±0.75	4.44±0.80			
Breaks between main meals [h]	3.58±0.85	3.62±0.80	3.56±0.89			

* p < 0.05 for the difference between non-snacking group and snacking group according to the Mann-Whitney test.

^a There were no statistically significant differences according to the Mann-Whitney test.

Table 2. Typical physical activity of the studied women during the intervention period, the study conducted at the dietician's office in Rybnik and the Jerzy Kukuczka Academy of Physical Education in Katowice, September–November 2020

Variable	Participants (N = 48) (M±SD)		
	total	non-snacking group (N = 21)	snacking group (N = 27)
DMPA [min/week]	68.96±47.52	71.67±51.95	66.85±44.68
EEMPA [kcal/week]	393.30±270.98	408.65±300.91	381.36±250.50
DVPA [min/week]	13.85±30.95	14.76±32.81	13.15±30.04
EEVPA [kcal/week]	116.59±265.69	123.19±280.61	111.46±258.79
DM-VPA [min/week]	82.81±56.85	86.43±61.50	80.00±53.98
EEM-VPA [kcal/week]	514.71±392.25	537.55±423.93	496.95±373.02

DMPA – duration of moderate physical activity (4 METs); DM-VPA – duration of moderate to vigorous physical activity; DVPA – duration of vigorous physical activity (6 METs); EEMPA – energy expenditure of moderate physical activity; EEM-VPA – energy expenditure of moderate to vigorous physical activity; EEVPA – energy expenditure of vigorous physical activity.

There were no statistically significant differences according to the Mann-Whitney test.

the other group of women who had 1–5 healthy and unhealthy snacks per day, which increased their daily calorie intake [43] by ca. 110 kcal more compared with the NS group and triggered an extra release of insulin inhibiting fatty acid oxidation and fat tissue reduction [13,44]. The baseline concentrations of insulin exceeded the upper limit of normal by almost 2-fold in both groups, being higher by 11% in the S group. The HOMA-IR index, a measure of insulin resistance and a predictor of cardio-metabolic risk in non-diabetic women ages <50 years old [45], exceeded its cut-off value of 2.5 in both groups and was higher in the S group by 9%. This suggested that study participants may have developed IR.

The intervention was designed to reduce calorie intake by 30% as well as the proportion of saturated fatty acids and simple carbohydrates and to increase the dietary content of fiber. As a result, it lessened the anthropometric risk factors for metabolic syndrome in all participants. The participants' body mass decreased by an average of 8%, mainly due to fat tissue reduction (by 5.8% on average). This improved their BMI by 7%, WC by 5.8%, HC by

3.8%, and WHR by 5.8%. In a study [46] with former athletes whose daily calorie intake was reduced for 6 weeks by 20% and 30%, respectively, compared with their total daily energy expenditure, a greater improvement in the body composition variables was recorded in the second group. Insulin resistance results from obesity and overweight are mainly caused by unhealthy eating and snacking [47]. Increasing insulin resistance causes fat tissue to release substances such as adiponectin, growth factors, and free fatty acids that enter hepatic circulation and damage the liver tissue [48], further adding to IR. Research has shown that decreased insulin sensitivity, which may precede the occurrence of T2DM by >10 years, is an independent and strong factor contributing to its development [49,50]. It has also been demonstrated that the rhythm of insulin secretion can be improved by regular meals and abstaining from snacks with a high glycaemic load and index [51].

Numerous studies indicate that reducing body mass by means of a restricted calorie intake raises insulin sensitivity, protects pancreatic beta cells, and prevents the pro-

Table 3. Changes in the variables in the studied women between baseline and month 3, the study conducted at the dietician's office in Rybnik and the Jerzy Kukuczka Academy of Physical Education in Katowice, September–November 2020

Variable	Participants (N = 48) (M±SD)			
	non-snacking group (N = 21)		snacking group (N = 27)	
	M±SD	effect size	M±SD	effect size
Anthropometric				
body mass [kg]				
baseline	79.21±11.74		78.11±12.27	
month 3	72.58±11.99 ^{a***}	0.56 ^{dc}	71.17±12.28 ^{a***}	0.57 ^{dc}
BMI [kg/m ²]				
baseline	28.61±2.90		28.70±3.73	
month 3	26.17±2.87 ^{a***}	0.84 ^{dc}	26.14±3.75 ^{a***}	0.69 ^{dc}
waist circumference [cm]				
baseline	86.00±6.79		86.00±8.44	
month 3	81.76±7.52 ^{a***}	0.58 ^{dc}	81.41±7.68 ^{b***}	0.88 ^f
hip circumference [cm]				
baseline	105.14±8.11		104.85±6.94	
month 3	101.05±7.29 ^{a***}	0.50 ^{dc}	101.00±6.60 ^{b***}	0.88 ^f
waist-to-hip ratio				
baseline	0.82±0.05		0.82±0.06	
month 3	0.81±0.06 ^b	0.28 ^f	0.81±0.07 ^{b*}	0.40 ^f
body fat [%]				
baseline	34.30±4.75		35.46±5.36	
month 3	32.08±4.88 ^{a***}	0.46 ^{dc}	32.37±4.87 ^{a***}	0.59 ^{dc}
Biochemical				
glucose [mmol/l]				
baseline	5.94±0.52		5.84±0.60	
month 3	4.89±0.60 ^{a***}	1.87 ^{dc}	4.98±0.62 ^{a***}	1.41 ^{dc}
insulin [mU/l]				
baseline	29.71±13.50		32.99±10.45	
month 3	27.68±15.26 ^b	0.26 ^f	20.76±10.09 ^{a***}	1.19 ^{dc}
HOMA-IR				
baseline	7.85±3.64		8.63±3.17	
month 3	5.91±3.18 ^{b**}	0.57 ^f	4.67±2.52 ^{a***}	1.37 ^{dc}
cholesterol [mg/dl]				
total				
baseline	193.38±30.78		199.47±25.59	
month 3	170.40±19.74 ^{b***}	0.88 ^f	164.89±14.73 ^{b***}	0.87 ^f

Table 3. Changes in the variables in the studied women between baseline and month 3, the study conducted at the dietician's office in Rybnik and the Jerzy Kukuczka Academy of Physical Education in Katowice, September–November 2020 – cont.

Variable	Participants (N = 48) (M±SD)			
	non-snacking group (N = 21)		snacking group (N = 27)	
	M±SD	effect size	M±SD	effect size
Biochemical – cont.				
LDL				
baseline	116.71±21.32		124.84±20.42	
month 3	96.32±12.74 ^{a***}	1.10 ^{dc}	90.03±13.87 ^{a***}	1.94 ^{dc}
HDL				
baseline	46.92±11.91		47.50±11.22	
month 3	52.43±10.82 ^{b***}	0.83 ^r	55.37±8.87 ^{a***}	0.76 ^{dc}
TG [mg/dl]				
baseline	135.67±35.83		129.70±40.07	
month 3	105.14±34.61 ^{a***}	0.87 ^{dc}	97.59±31.69 ^{b***}	0.87 ^r
TC/HDL				
baseline	4.27±0.79		4.34±0.77	
month 3	3.33±0.46 ^{a***}	1.34 ^{dc}	3.04±0.45 ^{a***}	1.88 ^{dc}
LDL/HDL				
baseline	2.61±0.70		2.75±0.72	
month 3	1.91±0.44 ^{b***}	0.88 ^r	1.68±0.41 ^{a***}	1.65 ^{dc}
TG/HDL				
baseline	3.03±0.99		2.82±0.94	
month 3	2.08±0.75 ^{b***}	0.88 ^r	1.80±0.67 ^{a***}	1.19 ^{dc}
atherogenic index of plasma				
baseline	0.10±0.15		0.06±0.17	
month 3	−0.07±0.17 ^{b***}	0.88 ^r	−0.13±0.16 ^{b***}	0.86 ^r

HDL – high-density lipoprotein, LDL – low-density lipoprotein, TC – total cholesterol, TG – triglycerides.

HOMA-IR – Homeostatic Model Assessment of Insulin Resistance.

* p < 0.05; ** p < 0.01; *** p < 0.001 for the difference between post-intervention and baseline measurements.

^a paired-samples t-test; ^b Wilcoxon signed-rank test.

Cohen's d (dc) – paired samples t-test effect size (0.2 to <0.3 – small effect, 0.5 to <0.8 – medium effect, and ≥0.8 large effect); r – Wilcoxon signed-rank test effect size (0.1 to <0.3 – small effect, 0.3 to <0.5 – medium effect, ≥0.5 – large effect).

gression of prediabetes to diabetes [52–54]. An improvement in insulin sensitivity was observed in healthy people with a short-term and very low-calorie diet, where caloric consumption was 500 kcal/day [55]. The diet reduced the abdominal adipose tissue and adipocyte size.

In another study with men and women aged 45–65 years, a calorie restriction diet reduced insulin and glucose levels and improved insulin sensitivity [56].

The calorie restriction intervention in this study improved blood insulin concentrations in both groups, re-

ducing them by nearly 6% in the NS group and as much as 37% in the S group. Although the HOMA-IR index at month 3 was still above the cut-off for cardio-metabolic risk [44], in the NS group it decreased by 25% while in the S group by almost 45%.

Insulin resistance and type 2 diabetes are reported to be associated with the clustering of interrelated plasma lipid and lipoprotein abnormalities, such as reduced HDL-C, LDL-C (>115 mg/dl), and TG (>150 mg/dl) [57,58]. These lipid profile markers are less useful in predicting the risk of cardiovascular diseases than the AIP, TC/HDL-C, LDL-C-HDL-C, and TG/HDL-C ratios that were used in this study [34,59,60].

The only lipid profile marker in this study that exceeded the normal range at the baseline was the concentration of LDL-C. In the S group it was almost 7% higher than in the NS group, likely because the snacking participants consumed more calories and cholesterol. Apart from the TC/HDL ratio, whose value was slightly elevated above normal, neither the LDL-C/HDL-C ratio nor the TG/HDL-C ratio suggested that any of the study participants might have been affected by lipid disorders [61].

The lipid profiles measured at month 3 were significantly better in all participants, especially in the S group, where the concentration of LDL-C decreased more than in the NS group (27% vs. 17%). This finding is consistent with the reports of other authors [46,61], who also found study participants' lipid profiles to have improved after several weeks of calorie restriction and demonstrated that overeating and snacking lead to obesity and overweight associated with unhealthy blood lipid profiles. For instance, Hołowko et al. [46] have shown that reducing the daily caloric intake by 30% of total daily energy expenditure for 6 weeks is capable of improving the body composition and lipid profiles of individuals with elevated cholesterol levels. In another study [61], a CR diet was found to have a powerful protective effect against atherosclerosis. There is also evidence that reducing the daily intake of calories, fatty acids, and simple

carbohydrates and increasing the proportion of polyunsaturated fatty acids and fiber in the diet can significantly curtail the prevalence of cardiovascular diseases and lower the concentration of LDL-C by even as much as 5–10% [62].

Study limitations

The 3 main limitations of the present study consist of the small sample size, non-random selection of study participants, and lack of a control group for comparison purposes.

CONCLUSIONS

The study has shown the following:

- a 3-month calorie restriction diet can improve the anthropometric parameters, HOMA-IR indexes, and lipid profiles of women with overweight or obesity who are physically inactive;
- regular meals without snacking can influence the glycemic levels and sensitization of cells to insulin (women who had snacked before the intervention had lower levels of insulin, LDL-C, and HOMA-IR indices);
- a calorie restriction diet can be recommended as a means of preventing the development of cardiovascular diseases.

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