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ORIGINAL ARTICLES

IMPROVEMENT IN ANTHROPOMETRIC PARAMETERS AFTER RATIONAL DIETARY INTERVENTION IN WOMEN WITH POLYCYSTIC OVARY SYNDROME AS THE BEST METHOD TO SUPPORT TREATMENT

Małgorzata Szczuko[1], Inez Malarczyk[1], Marta Zapałowska-Chwyć[2]*

[1]Pomeranian Medical University in Szczecin, Faculty of Health Sciences,
Department of Biochemistry and Human Nutrition, Broniewskiego 24, 71-460 Szczecin, Poland
[2]Pomeranian Medical University in Szczecin,
Clinic of Gynecology and Urogynecology, Broniewskiego 24, 71-460 Szczecin, Poland

ABSTRACT

Background. Polycystic ovary syndrome (PCOS) is a disorder often occurring in women at reproductive age. An important factor in PCOS pathogenesis is insulin resistance, which pronounces hyperandrogenism and leads to the development of various metabolic disorders.

Objectives. The aim of this study is to determine the effect of reduction diet with low glycemic index (GI) on anthropometric parameters of women with PCOS and the assessment of the effectiveness of the diet on body mass and adipose tissue reduction.

Material and methods. The study was performed on 24 women with PCOS diagnosed with Rotterdam's criteria. Anthropometric measurements and bioelectrical impedance were performed. All participants received 7-day diet and recommendations relating to the change in lifestyle. After three months of using the dietary recommendations the measurements were repeated.

Results. Statistical significance was observed for body mass (↓on average by 5.93 kg±2.95), BMI (↓2.14 kg/m2±1.2), circumference of: waist (↓7.7 cm±5.9), hip (↓4.8 cm±5.4), arm (↓1.9 cm±3.7) and measurements of skin fold under the shoulder blade (↓4.8 mm±4,6), above iliac crest (↓6.76 mm±5.7) and above triceps brachii muscle (↓5.25 mm±7.4). Considering body composition measurements, statistically significant were differences in the measurements of BCMI (↑18.042±8.8), TBW expressed in percentage (↑2.729±2.75) and in litres (↑0.071±5.15), FM in percentage (↓3.291±5.6) and in kg (3.354 kg±4.9).

Conclusions. Body mass reduction using a rational diet with low GI is an effective method to support of PCOS treatment. Using reduction diet for three months together with increased physical activity enables to reduce body weight by on average 5.93 kg, which increases the chances to treat infertility in women. This should be the suggested type of diet in PCOS treatment.

Key words: *polycystic ovary syndrome, PCOS, reduction diet, fat mass, anthropometric measurements*

STRESZCZENIE

Wprowadzenie. Zespół policystycznych jajników (PCOS) to zaburzenie coraz częściej pojawiające się wśród kobiet w wieku reprodukcyjnym. Ważnym czynnikiem w patogenezie PCOS jest insulinooporność, która nasila hiperandrogenizm oraz prowadzi do rozwoju zaburzeń metabolicznych, w tym zespołu metabolicznego.

Cel. Celem badań jest ocena wpływu stosowania diety redukcyjnej o niskim indeksie glikemicznym na parametry antropometryczne kobiet z PCOS oraz ocena skuteczności diety na redukcję masy ciała i tkanki tłuszczowej.

Materiał i metody. Badanie przeprowadzono wśród 24 kobiet ze stwierdzonym zespołem policystycznych jajników, według kryteriów Rotterdamskich. Wykonano pomiary antropometryczne metodą bioimpedancji elektrycznej. Każda z uczestniczek badania otrzymała siedmiodniowy jadłospis oraz zalecenia odnoszące się do zmiany stylu życia. Po trzech miesiącach stosowania zaleceń dietetycznych pomiary powtórzono.

Wyniki: Statystyczną istotność wykazano w zmianie masy ciała (↓średnio o 5,93 kg ±2,95), BMI (↓2,14 kg/m^2± 1,2), obwodach: talii (↓7,7cm ± 5,9), bioder (↓4,8 cm ± 5,4), ramienia (↓1,9 cm ± 3,7) oraz pomiarach fałdów skórno-tłuszczowych pod łopatką (↓4,8 mm ± 4,6), nad grzebieniem kości biodrowej (↓6,76 mm ± 5,7), nad mięśniem trójgłowym ramienia

[*] **Corresponding author:** Małgorzata Szczuko, Pomeranian Medical University, Faculty of Health Sciences, Department of Biochemistry and Human Nutrition, 24 Broniewskiego str., 71-460 Szczecin, Poland; phone: +48 91 441 4806; fax. +48 91 441 4807, e-mail: malgorzata.szczuko@pum.edu.pl

(↓5,25 mm ± 7,4). Z pomiarów składu ciała, statystycznie istotne okazały się różnice w pomiarach BCMI (↑18,042 ± 8,8), TBW w organizmie wyrażonej procentowo (↑2,729 ± 2,75) i w litrach (↑0,071 ± 5,15), odsetka FM (↓3,291 ± 5,6) oraz wyrażonej w kilogramach (3,354kg ± 4,9).

Wnioski. Redukcja masy ciała przy zastosowaniu racjonalnej diety opartej na piramidzie zdrowego żywienia i niskim IG jest skuteczną metodą wspomagającą leczenie PCOS. Stosowanie przez okres trzech miesięcy diety redukcyjnej, połączonej ze zwiększoną aktywnością fizyczną, pozwala na redukcję masy ciała średnio o 5,93 kg co zwiększa szansę powodzenia w leczeniu bezpłodności kobiet. Ten typ diety powinien być sugerowany w leczeniu kobiet z PCOS.

Słowa kluczowe: *zespół policystycznych jajników, PCOS, dieta redukcyjna, tkanka tłuszczowa, pomiary antropometryczne*

INTRODUCTION

Polycystic ovary syndrome (PCOS) is a disorder often occurring in women at reproductive age. It is estimated that 15% of women suffer from PCOS [8]. An important factor in PCOS pathogenesis is the presence of insulin resistance, which strengthens hyperandrogenism and leads to metabolic disorders [16, 22]. Body mass reduction is widely used in the treatment of the most common metabolic diseases: type 2 diabetes, hypertension or atherosclerosis, which are the components of metabolic syndrome often occurring among women with PCOS [2]. All these diseases increase the risk of other diseases, especially at menopause [35]. Does the reduction of body mass give any positive effects in PCOS treatment? The answer to this question was provided in the studies by *Kiddy* et al. [14], in which the effectiveness in PCOS treatment was visible with 5% reduction of body mass. Similar approach was taken by *Guzick* et al. [11], who proved that the diet providing lowered energy – compared to the demand – improved the concentration of insulin, SHGB, androgens and reduced insulin resistance of tissues [4].

Adipose tissue is an important endocrine organ which is a source of adipokines. These are responsible for maintaining appropriate energetic state of the organism, affect the mechanisms of hunger and satiety and hormonal balance [28]. Adipokines also influence the metabolism of glucose and lipids, and thus affect the development of insulin resistance and hyperinsulinemia [27]. The substances secreted by adipose tissue cells include leptin, resistin and cytokines: TNF-α and Il-6 [10]. In case of obese women with PCOS with excessive adipose tissue, hyperinsulinemia has the following effects:

1) increased synthesis of androgens by ovaries, on which there are insulin receptors [26],
2) increased synthesis of adrenal androgens through elevated activity of the axis hypothalamus – pituitary – adrenal glands [21],
3) inhibition of SHBG (sex hormone binding globulin) synthesis in liver, which in turn increases free (active) androgen fractions [12],
4) stimulation of the activity of a protein regulating one of the stages of steroidogenesis – StAR [29].

All these mechanisms lead to hyperandrogenism, ovarian enlargement and infertility. Despite visible effects of dietetic interventions on the state of patients with polycystic ovary syndrome, so far no detailed criteria have been developed with respect to the type of diet having the most beneficial effect on the improvement of disrupted activity of ovaries and simultaneously leading to body weight reduction.

The aim of this study is to determine the effect of low glycaemic index (GI) reduction diet in agreement with the rules of rational nutrition on anthropometric parameters of women with PCOS and the assessment of the effectiveness of the diet on body mass reduction.

MATERIALS AND METHODS

Test group

The study was approved by the Ethics Committee of the Bioethical Commission of the Pomeranian Medical University in Szczecin. Diagnostic screening tests for PCOS were performed on 34 women aged from 17 to 38 in the Clinic of Gynecology and Urogynecology. PCOS diagnosis was made according to Rotterdam's criteria, 2 out of 3 following criteria: rare ovulations or lack of thereof, and/or biochemical symptoms of hyperandrogenism, and/or image of polycystic ovaries in USG (Ultrasound Voluson 730, GE, Switzerland). After 3 months of using the diet 3 women were excluded from the test group due to pregnancy and 7 women did not report for control examination. The final test group comprised of 24 women with PCOS.

Anthropometric measurements

All participants of the study were subjected to anthropometric bioelectrical impedance (BIA) measurements. The following measurements were taken: body mass (±0,1 kg), height (±0,5cm), circumference of waist (±0,5 cm), hip (±0,5 cm), arm of nondominant hand (±0,5cm). Skinfold thickness under the shoulder blade (±0,1 cm), above iliac crest (±0,1 cm) and above triceps brachii muscle (±0,1cm)

by caliper (Holtain). BMI and WHR indexes were calculated from obtained results. Using BIA 101 (Akern, Italy) the following characteristics were taken: phase angle – PA, fat mass – FM (kg,%), fat-free mass – FFM (kg,%), muscle mass – MM (kg,%), total body water – TBW (L,%), including intracellular water – ICW and extracellular water – ECW, sodium to potassium ratio – Na:K and basal metabolic rate – BMR (kJ, kcal). After three months of using the diet the measurements were repeated.

Dietary intervention

Each female participant received a seven-day menu with the recommendations regarding the change of lifestyle [33]. The menu was individually adjusted to each patient's requirements and the caloricity of the diet was reduced by 600 kcal. The diet consisted of 5 meals per day. All products were given in grams and/or cooking weights and measures. Food products recommended in the diets were the sources of all macronutrients, in accordance with the food pyramid recommended by the National Food and Nutrition Institute in Warsaw. Each meal was composed based on the sources of carbohydrates, protein and fats. The products used as the sources of carbohydrates (5 portions per day) were: oatmeal, wholegrain rye bread or graham bread, brown rice, groats (wheat, millet and buckwheat), sporadically potatoes and wholemeal pasta with lowered glycemic indexes.

As the source of protein in the recommended diet (on average 1 portion of meat and 2 portions of dairy products per day) were: eggs, lean meat without skin (turkey, chicken), fish (sole, salmon, tuna), semi skimmed milk (2% of fat) and dairy products (quark, natural yoghurt and buttermilk with 2% of fat), nuts and seeds (almonds, pumpkin seeds and sunflower seeds) and legumes (soy, red lentils, beans and peas). The diet also included low GI fruits and vegetables in every meal to supplement the diet with vitamins and minerals.

As the sources of fat (2 portions per day, on average) the following products were used in the diet: raw cold oils (rapeseed oil, olive oil), oily fruits, such as avocado. The sources of fat were also nuts, fish, meat and dairy products. Cod liver oil was recommended from October to April.

The patients were recommended to use braising, roasting, cooking in water and steaming as heat treatment techniques to prepare their food. Additionally, each patient was instructed to drink approximately 2 litres of fluids during the day. The recommended drinks included iodized water and herbal infusions. The average ratio of energy was up to 20% from protein, up to 30% from fat and ca. 50% from carbohydrates. The average content of nutrients, cholesterol and dietary fibre for 1600 and 1800 kcal diets and the structure of macronutrients are presented in Table 1. The diet was supplemented by seeds rich in calcium, such as sesame seeds and poppy seeds.

All female participants of the study were characterized by lowered physical activity – at the level of PAL 1.3 – 1.4. Due to that one of the requirements given with the menus was to increase physical activity to minimum 3 hours a week. Control visits in the dietary office were carried out once a month.

Statistical analysis

Statistica 12.0 (Statsoft, Tulsa, Oklahoma, USA) was used for statistical analyses. The results are expressed as the mean ± standard deviation. As the distribution in most cases deviated from normal (*Shapiro-Wilk* test), the non-parametric *Mann-Whitney* test was used for comparisons between two groups, and $p<0.05$ was considered as statistically significant.

RESULTS

Before the dietary intervention, the ratio of women with appropriate body weight was 21%, 37% were overweight, 29% women were with first degree of obesity, 4% with second degree of obesity and 8% - with third degree of obesity (Figure 1). After three months, the results were as follows: 42% of women had appropriate body weight, 25% were overweight, 21% were with first degree of obesity and the ratio of women with second and third degree of obesity remained unchanged (Figure 1). Visceral obesity (WHR) before dietary intervention was observed in 84% of women. After three months WHR >0,8 was observed only in 67% of patients.

Statistical significance at the level of $p\leq0.05$ was shown for body mass (BM) (↓on average by 5.93 kg ±2.95), BMI (↓2.14 kg/m^2±1.2), circumference of: waist (↓7.7 cm±5.9), hip (↓4.8 cm ±5.4), arm (↓1.9 cm±3.7) and for measurements of skin fold under the shoulder blade (↓4.8 mm±4.6), above iliac crest (↓6.76 mm±5.7) and above triceps brachii muscle (↓5.25 mm±7.4) (Table 2). Statistically significant reduction in body composition parameters measured using BIA related to: BCMI (↑18.042±8.8), TBW expressed in percentage (↑2.729±2.75) and in litres (↑0.071 L±5.15), FM in percentage (↓3.291±5.6) and in kg (3.354 kg±4.9), Figure 2. Other changes in measured parameters were not statistically significant (Table 3).

Improvement has been noticed in almost all biochemical parameters. However, statistically significant changes were observed only in the reduction of lipid fractions: triglycerides by ca. 30 units, LDL by ca. 25 units and total cholesterol by ca. 20 units (Table 4).

Table 1. Average content of nutrients in 1600 and 1800 kcal diets

Component	Average 1600 kcal	SD	Average 1800 kcal	SD
Energy [kJ]	6930.79	437.18	7882.02	445.43
Energy [kcal]	1634.98	105.57	1822.16	107.53
Water [g]	1227.30	144.28	1321.30	151.28
Total protein [g]	84.61	10.99	93.52	12.41
Animal protein [g]	47.12	13.40	51.58	15.17
Plant protein [g]	34.85	8.64	39.30	9.36
Total fat [g]	54.05	8.54	62.64	9.43
Total fatty acids: saturated [g]	14.57	2.86	18.07	4.63
Total fatty acids: monounsaturated [g]	23.47	5.21	26.28	4.30
Total fatty acids: polyunsaturated [g]	11.64	2.46	13.41	2.96
Cholesterol [g]	154.69	59.72	178.51	68.71
Total carbohydrates [g]	238.84	22.91	271.38	22.09
Absorbable carbohydrates [g]	205.35	20.55	233.70	20.62
Ash [g]	15.41	0.46	17.26	0.65
Sodium [mg]	1402.94	375.14	1691.99	491.74
Potassium [mg]	4055.60	680.11	4421.33	649.54
Calcium [mg]	966.80	278.25	1032.31	279.11
Phosphorus [mg]	1728.82	167.04	1910.24	194.73
Magnesium [mg]	482.17	18.75	533.72	26.36
Iron [mg]	13.10	1.92	14.55	1.89
Zinc [mg]	12.19	0.86	13.70	1.08
Copper [mg]	1.66	0.27	1.84	0.25
Manganese [mg]	7.20	1.29	8.08	1.52
Vitamin A (retinol eq.)	1725.46	765.24	1766.58	760.49
Retinol	187.17	60.07	220.02	64.56
Beta-carotene	9230.57	4348.32	9280.41	4331.15
Vitamin E (alfa-tocopherol eq.)	16.00	3.56	17.05	3.28
Thiamine [mg]	1.65	0.24	1.81	0.22
Riboflavin [mg]	2.00	0.21	2.15	0.24
Niacin [mg]	21.31	2.38	24.04	1.83
Vitamin B6	2.66	0.60	2.89	0.58
Vitamin C [mg]	302.12	100.19	320.84	102.24
Cholesterol [g]	154.69	59.72	178.51	68.71
Sucrose [g]	17.14	5.34	20.73	6.29
Lactose [g]	17.19	9.48	18.31	8.76
Starch [g]	109.96	29.51	128.96	35.95
Dietary fibre [g]	33.49	5.41	37.68	4.88
Folacin/folic acid [µg]	557.26	122.99	593.52	117.26
Vitamin B12 [µg]	3.83	1.55	4.07	1.46
Vitamin D [µg]	3.47	3.77	3.52	3.76
Iodine [µg]	57.20	13.52	59.17	11.91
Energy % from protein [%]	20.77	2.73	20.16	2.79
Energy % from fat [%]	28.76	3.44	29.32	3.19
Energy % from carbohydrates [%]	50.47	4.63	50.52	4.38

Table 2. Descriptive statistics of anthropometric parameters before and after dietary intervention

Parameter	Before intervention $\bar{x}$ ± SD	After intervention $\bar{x}$ ± SD	Z	p
Body mass [kg]	83.75 ± 15.4	77.82 ± 15.3	4.23	**0.000***
BMI [kg/m^2]	30.13 ± 6.60	28.09 ± 6.33	4.23	**0.000***
WHR	0.93 ± 0.071	0.90 ± 0.10	2.51	**0.012***
Waist circumference [cm]	102.52 ± 14.51	94.79 ± 16.01	3.94	**0.000***
Hip circumference [cm]	109.79 ± 9.36	104.96 ± 9.14	3.59	**0.000***
Arm circumference [cm]	31.98 ± 5.65	30.09 ± 4.70	3.11	**0.002***
Skinfold below shoulder blade [mm]	28.18 ± 8.41	23.37 ± 7.04	3.59	**0.000***
Skinfold above iliac crest [mm]	31.02 ± 7.14	24.26 ± 8.07	3.81	**0.000***
Skinfold above triceps brachii muscle [mm]	25.75 ± 7.79	20.50 ± 7.53	2.92	**0.004***

*statistically significant with p<0.05

Table 3. Descriptive statistics of results of bioelectrical impedance before and after dietary intervention

Parameter	Before intervention $\bar{x}$ ± SD	After intervention $\bar{x}$ ± SD	Z	p
Phase angle	7.03 ± 5.75	6.05 ±1.49	0.02	0.988
FM [%]	39.14 ± 8.64	35.85 ± 6.25	3.14	**0.002***
FM [kg]	33.03 ± 11.45	29.68 ± 10.87	3.51	**0.000***
MM [%]	44.48 ± 13.12	44.60 ± 8.81	0.54	0.587
MM [kg]	35.50 ± 7.51	34.37 ± 7.03	0.67	0.502
TBW [%]	44.24 ± 4.91	46.97 ± 4.57	3.96	**0.000***
TBW [L]	36.12 ± 5.80	36.19 ± 4.27	1.95	**0.052****
ICW [%]	53.24 ± 5.0	53.70 ± 6.41	0.27	0.786
ICW [L]	21.22 ± 7.50	19.43 ± 3.26	1.49	0.137
ECW [%]	45.27 ± 7.97	46.28 ± 6.39	0.41	0.679
ECW [L]	16.68 ± 3.34	16.76 ± 2.93	0.68	0.494
Na : P	0.97 ± 0.16	0.94 ± 0.17	0.97	0.331
PPM [kcal]	1514.4 ±149.3	1513.0 ±134.0	0.09	0.932
BCMI	9.60 ± 2.24	27.64 ± 8.79	4.29	**0.000***
BCM [%]	51.58 ± 7.36	53.40 ± 7.36	0.79	0.432
BCM [kg]	26.70 ± 7.03	27.64 ± 8.79	0.41	0.679

*statistically significant with p<0.05; ** statistically significant with p<0.1

Table 4. The biochemical data of patients with PCOS before and after dietary intervention

Parameter	PCOS before dietary intervention	PCOS after dietary intervention	P value
Glucose [mg/dl]	92.95 ± 10.03	89.59 ± 6.68	NS
Insulin [uU/ml]	13.98 ± 10.76	10.65 ± 4.04	NS
Cholesterol [mg/dl]	179.43 ± 29.51	159.79 ± 27.21	0.019
LDL [mg/dl]	114.98 ± 32.93	89.62 ± 28.34	0.007
TG [mg/dl]	107.92 ± 51.87	77.62 ± 32.2	0.014
HDL [mg/dl]	54.44 ± 17.31	58.94 ± 17.23	NS
Androstendion [ng/m]	4.03 ± 1.56	4.24 ± 1.56	NS
Testosteron [ng/m]	0.69 ± 0.18	0.52 ± 0.14	NS

DISCUSSION

Even though obesity is not regarded as the cause in the development of polycystic ovary syndrome [37], it was observed, similarly as in this study, that reduction in body weight brings many benefits and is the best method of treatment for women with PCOS [1]. Body mass reduction is so beneficial that it is even achieved in patients through bariatric surgeries. It contributes to improvement in parameters indicative of metabolic disorder and affects the regulation of menstrual cycles. However, in case of bariatric procedure the patient is not

taught new rational eating habits and healthy lifestyle, and her self-assessment decreases despite body mass reduction [5]. Therefore, the best method of weight reduction is appropriate diet and increased physical activity. Many surveys consider insulin resistance and the effect of steroid hormones on metabolism [13, 14]. It was also stressed that the occurrence of polycystic ovaries is genetically dependent [38]. Even though no specific genes predisposing for PCOS were found, many studies concentrate on genes engaged in the development of inflammatory reaction taking part in biosynthesis and function of insulin and development of insulin resistance. Among the genes involved in biosynthesis, transport and function of androgens (CYP 11, CYP 17, StAR, HSD17B1-3, HSD17B1-2) [35], most attention is put to gene CYP17 encoding for one of the enzymes from cytochrome P450 family, responsible for the conversion of C21-steroids to androgens [19]. The concentration of steroid hormones in plasma positively correlates with BMI. Especially testosterone, after reaching target tissues, undergoes transformation (by 5α-reductase) to stronger androgen - 5α-dihydrotestosterone (DHT). The activity of 5α-reductase enzyme is much higher in women with PCOS than in the control group of healthy women [1]. Based on these data it can be assumed that body mass reduction, occurring along with the reduction of adipose tissue, can reduce the number of target cells in which testosterone is converted into active forms, and thus can alleviate potential clinical symptoms.

In this work, we presented the study based on three-month change of lifestyle, which included increased physical activity (min 3 hours a week) and adhering to recommendation of low calorie diet. The diet was composed following the rules of rational nutrition. Recommended menus were in majority composed of carbohydrate products providing 50% of energy. Protein supplied 20% of energy and fats – almost 30%. There are numerous studies which show the reduction of body weight and other anthropometric parameters after dietary intervention in women with PCOS [9, 14, 16, 20, 34]. However, in other studies other variants of diets were used (high protein diet, diets rich in fat and caloric restrictions even below BMR) with various intensity of physical activity. Our diet contains a proper proportion of nutrients without modulating their percentage composition.

Lower caloric load of the diet and increased physical activity lead to reduction in insulin resistance of the tissues, which lowered the level of insulin and increased the use of energy by the tissues, which in turn contributed to body mass reduction [14, 18]. Low-calorie diet, low in fat, with reduced content of saturated fatty acids and low glycaemic index (GI) carbohydrates was used by *Marsh* et al. Group of patients adhering to the above mentioned requirements was compared to the control group using the same type of diet – of lowered caloricity compared to energy demand, but different in glycaemic index of used carbohydrates. As a result, it was observed that low GI diet has more beneficial effect on the regulation of menstrual cycle (improvement in 95% of examined women) that higher GI diet (improvement in 63% of examined)[18].

Despite the attempts to compare the effectiveness of high protein to low protein diets, no statistical differences were observed in body mass reduction, total content of fat, fat free body mass and the amount of visceral fat [20]. Caloric restrictions and increased energy expenditure through increased physical activity were used in randomized study aimed to eliminate the resistance to synthetic form of oestrogen (*clomiphene citrate*) in obese women with PCOS [25]. The aim was reached together with reduced body weight, waist circumference, BMI and WHR. The effect of diet rich in polyunsaturated fats was also observed [12]. To establish its effectiveness, the women participating in the study were given lower calorie diet with standard fat contents but with increased ratio of polyunsaturated fatty acids (PUFA). The study lasted three months after which the reduction in body weight and BMI were observed, but without significant changes in body composition and, which is less satisfying, in waist circumference. Increased consumption of PUFA, coming from walnuts, by women with PCOS affected glucose homeostasis, serum lipids concentration and hormonal regulation [13]. The dietary intervention results in reduced waist circumference and decrease WHR ratio.

In another study, the women with PCOS were divided into 3 groups. In the first group, body weight reduction was supposed to be achieved by low-calorie diet (DO group); in the second group, only the physical activity was introduced (DA group); in the third group, physical activity was combined with low-calorie diet (DC group). The results showed body mass reduction in all groups without significant differences between them. In DA and DC groups, the content of adipose tissue and fat free mass were reduced in comparison to DO group. Other analysed parameters were reduced in all the groups without significant differences [34]. DC group should revel better results, however the positive effects can be covert by muscle mass increased in the high physical activity groups. Other studies aimed to compare the benefits of low-calorie high protein diet (50% of energy from protein) and low-calorie-high carbohydrate diet. During this study a significant body mass reduction was observed in both groups (in group using high protein diet and in group using diet high in carbohydrates). Except that, no observable biometrical or hormonal differences between the groups were noted. However, it was observed that

among women using low-calorie high protein diet, waist circumference reduced more notably than in the group using diet rich in carbohydrates. On the other hand, the problem of hirsutism decreased in women on high carbohydrate diet [30]. Finally, those studies did not bring conclusive results, which would be helpful in determining the ratio of macronutrients in dietary treatment of PCOS.

Satisfactory reduction of body mass, achieved in a short period of time, leads to increased interest in diets with high fat (50-60% of energy) and protein content (20-30%) and with lowered level of carbohydrates (3-10% of energy) [15]. However, one should consider the means in which such results are achieved. High consumption of protein and fat with lower intake of carbohydrates results in changes in carbohydrate metabolism [7], which leads to limited use of glucose as energy source for muscles (biosynthesis of glucose transporter GLUT4 is inhibited). Stores of muscle glycogen are diminished and water content in the organism decreases [38]. Diets high in fat and low in carbohydrates are ketogenic and are characterized by high levels of ketone bodies in blood, produced during the metabolism of fatty acids as the source of energy. Ketone bodies, being the major source of energy for the central nervous system, reduce hunger and decrease the concentration of insulin [15,31]. People adhering to the recommendation of such diets, without supplementing appropriate amount of vegetables and fruits, intake too little dietary fibre, vitamins and minerals. High consumption of fats and proteins leads to reduced pH, contributes to positive nitrogen balance and to the increase in production of ammonia and urea, which overloads liver and kidneys [5,32]. Additionally, high level of phosphates supplied with high protein diets increased the risk of kidney stone disease. Ketogenic diets are usually abundant in products being the source of animal fats, which are more susceptible to the activity of reactive forms of oxygen. Moreover, such diets often do not supply proper amounts of antioxidants. Deficiencies in antioxidative enzymes are intensified when protein – also used as an energy substrate – is consumed in insufficient amounts [23]. By these means ketogenic diets affect free radical reactions, which can contribute to the damage of inner surface of artery walls. Next, an atherosclerotic plaque is formed due to the agglomeration of cholesterol, platelets and immune system cells in the damaged site and through the activation of inflammatory processes and the formation of foam cells by macrophages [3]. Diets high in fat were considered as harmful in 1999 by the Therapy and Drug Scientific Committee of Polish Academy of Sciences [24]. High protein diet (>30% of energy from protein) also increases the risk of cardiovascular diseases, liver and kidneys diseases and osteoporosis [9]. With higher supply of protein and reduced intake of carbohydrates a higher protein metabolism is observed, which leads to increased thermogenesis. In case of women with PCOS we should take into consideration the risk of occurrence of several diseases (acne, androgenic alopecia, obesity, type II diabetes, fertility disorders, depression, lipid profile disorders, glucose metabolism disorders, metabolic syndrome, cardiovascular diseases, breast and endometrium cancers) and dietary recommendations should be as close to rational nutrition as possible, based on current food pyramid of the National Food and Nutrition Institute in Warsaw, Poland.

All examples of diets, given in discussed publications, seem to be useful in PCOS treatment, with respect to the composition of macronutrients. Most of them have low caloricity in common but not the content of nutrients (proteins, fat, carbohydrates). Using caloric restriction only, without the change in macronutrients ratio, gives visible and sufficient result in terms of changes in body composition and anthropometric parameters. Taking into consideration the importance of energetic restriction of a diet, if there are no differences with respect to prevailing nutrient, it should be stated that the most appropriate solution is the rational nutrition leading to loss of body weight prolonged in time. Additionally, it results in the acquisition of appropriate eating habits. It should be stressed that polycystic ovary syndrome is related to higher risk of other health problems. Starting from cardiovascular diseases, an organism of women with PCOS is more susceptible to developing insulin resistance, which leads to more rapid occurrence of disorders linked to cardiovascular diseases development. For such reason, it is worth considering whether recommending unconventional diets to women, who besides suffering from PCOS are also susceptible to metabolic syndrome and related complications, is appropriate. In our opinion, which we tried to show in this study, such approach could be an additional burden for already disturbed metabolism in these women.

Reduction diet, even though based on low glycemic index, did not significantly reduce the parameters of carbohydrates metabolism (glucose and insulin measured in fasting state). Moreover, it did not lead to significant increase of HDL level, which shows that not all dietary recommendations were used. Because the concentration of LDL and TG dramatically decreased, we think that the patients reduced the consumption of animal products and simple sugars, consumed recommended vegetable oils, but did not increased their physical activity, despite previous claims. It is known that physical activity contributes to the increase of HDL and the improvement of insulin resistance [17]. The lack of significant changes in androgens hormonal profile is, according to us, caused by its high

stability, in comparison to the lipid profile. Therefore, diet treatment of women with PCOS should last longer than three months. No significant differences in hormonal parameters were also observed by other researchers using high protein diet for one month [30]. However, after three months and the diet substituted with PUFA *Kasim-Karakas* et al. [13] observed the reduction in androgens. Recommend reduction diet, among women with PCOS and normal body fat (less than 25%) seems pointless.

CONCLUSIONS

1. The vast majority of women with PCOS have increased body weight and too much body fat. Most of the participants are exposed to metabolic syndrome.
2. Weight reduction using a rational low GI diet is a very effective way of supporting PCOS treatment.
3. A weight reduction diet combined with physical activity over a period of three months allows for a weight reduction of 5.93 kg on average.
4. After a period of three months most PCOS patients return to normal weight, the rest of the women require a longer period of dietary treatment.

Conflict of interest

The author has no conflict of interest to declare.

REFERENCES

1. *Barber T.M., McCarthy M.I., Wass J.A.H., Franks S.*: Obesity and polycystic ovary syndrome. Clinical Endocrinology 2006; 65:137–145
2. *Bednarek-Tupikowska G., Bucyk B.*: The metabolic effects of polycystic ovary syndrome. Family Medicine & Primary Care Review 2008;10(3):769–774.
3. *Beręsewicz A., Kurzelewski M.*: Patofizjologia ostrych zespołów wieńcowych. [Pathophysiology of acute coronary syndromes]. Medipress Kardiologia 2001; 8: 3-11.
4. *Białek A.*: Sprzężone dieny kwasu linolowego jako potencjalny czynnik prewencyjny w profilaktyce nowotworów piersi. [Conjugated linoleic acid as a potential protective factor in prevention of breast cancer]. Postępy Hig Med Dosw. 2013;67:6-14.
5. *Busetto L., Marangon M., de Stefano F.*: High-protein low-carbohydrate diets: what is the rationale?. Diabetes Metab Res Rev. 2011; 27(3): 230-232.
6. *Canetti L., Bachar E., Bonne O.*: Deterioration of mental health in bariatric surgery after 10 years despite successful weight loss. European J Clin Nutr. 2016; 70: 17–22, doi:10.1038/ejcn.2015.112
7. *Cha M.C., Johnson J.A., Hsu C.Y., Boozer C.N.*: High-fat hypocaloric diet modifies carbohydrate utilization of obese rats during weight loss. Am. J. Physiol Endocrinol Metab. 2001; 280: 797-803.
8. *Dniak-Nikolajew A.*: Zespół policystycznych jajników jako przyczyna niepłodności kobiecej [Polycystic ovary syndrome as a cause of female infertility]. Położna. Nauka i Praktyka 2012; 1(17):14-17.
9. *Fung T.T., Dam van R.M., Hankinson S.E., Stampfer M., Willett W.C., Hu F.B.*: Low-carbohydrate diets and all cause and cause-specific mortality. The cohort studies. Ann Intern Med. 2010; 153(5): 289–298.
10. *Guerre-Millo M.*: Adipose tissue and adipokines: for better or worse. Diabetes Metab. 2004; 30: 13–19.
11. *Guzick D.S., Wing R., Smith D., Berga S.L., Winters S.J.*: Endocrine consequences of weight loss in obese, hyperandrogenic, anovulatory women. Fertil Steril. 1994; 61: 598–604.
12. *Hautanen A.*: Synthesis and regulation of sex hormone-binding globulin in obesity. Intern J Obes. 2000; 24 (supl. 2): 64–70.
13. *Kasim-Karakas S.E., Almario R.U., Gregory B.L., Wong R., Todd H., Lasley B.L.*: Metabolic and Endocrine Effects of a Polyunsaturated Fatty Acid-Rich Diet in Polycystic Ovary Syndrome. J Clin Endocrinol Metab. 2004; 89(2): 615–620.
14. *Kiddy D.S., Hamilton-Fairley D., Bush A., Short F., Anyaoku V., Reed M.J.*: Improvement in endocrine and ovarian function during dietary treatment without dietary restriction. Int J Obes. 1999; 23: 1016–1024.
15. *Klosiewicz-Latoszek L.*: Charakterystyka i efektywność diet odchudzających. [Characteristics and effectiveness of weight loss diets]. Żyw Człow Metab. 2010; 37(3): 188–194.
16. *Kochan Z., Karbowska J., Babicz-Zielińska E.:* Trans-kwasy tłuszczowe w diecie – rola w rozwoju zespołu metabolicznego. Postępy Hig Med Dośw. 2010; 64: 650-658.
17. *Malara M., Lutosławska G.:* Physical activity, dietary habits and plasma lipoproteins in young men and women. Rocz Panstw Zakl Hig 2010; 61(4):405-412
18. *Marsh K.A., Steinbeck K.S., Atkinson F.S., Petocz P., Brand-Miller J.C.*: Effect of a low glycemic index compared with a conventional healthy diet on polycystic ovary syndrome. Am J Clin Nutr. 2010; 92: 83–92.
19. *Marszalek B., Lacinski M., Babych N., Capla E., Biernacka-Lukanty J., Warenik-Szymankiewicz A., Trzeciak W.H.*: Investigations on the genetic polymorphism in the region of CYP17 gene encoding 5'-UTR in patients with polycystic ovarian syndrome. Gynecol Endocrinol. 2001; 15: 123-128.
20. *Moran L.J., Noakes M., Clifton P.M., Tomlinson L., Norman R.J.*: Dietary Composition in Restoring Reproductive and Metabolic Physiology in Overweight Women with Polycystic Ovary Syndrome. J Clin Endocrinol Metab. 2003; 88(2): 812–819.
21. *Morin-Papunen L.C., Vauhkonen I., Koivunen R.M., Ruokonen A., Tapanainen J.S.*: Insulin sensitivity, insulin secretion, and metabolic hormonal parameters in healthy women and women with polycystic ovary syndrome. Hum. Reprod. 2000; 15: 1266–1274.
22. *Muoio D.M, Newgard C.B.*: Mechanisms of disease: molecular and metabolic mechanisms of insulin resistance and beta-cell failure in type 2 diabetes. Nat Rev Mol Cell Biol. 2008; 9: 193-205.

23. *Nazarewicz R.:* Konsekwencje stosowania wysokotłuszczowych diet ketogennych. [Consequences of using rich in fat ketogenic diets]. Bromat Chem Toksykol. 2007; XL. 4: 371 – 374.
24. *Ostrowska L., Karczewski J.:* Czy dieta tłuszczowa Kwaśniewskiego może być zalecana w leczeniu otyłości? Ocena składu diety. [Should Kwaśniewski's fat diet be recommended in obesity treatment? Assessment of diet composition]. Med. Metabol. 2002; 6:69.
25. *Palomba S., Falbo A., Giallauria F.*: Six weeks of structured exercise training and hypocaloric diet increases the probability of ovulation after clomiphene citrate in overweight and obese patients with polycystic ovary syndrome: a randomized controlled trial. Hum Reprod. 2010; 25(11): 2783-2791.
26. *Poretsky L., Cataldo N.A., Rosenwaks Z., Giudice L.C.*: The insulin-related ovarian regulatory system in health and disease. Endocr. Rev. 1999; 20: 535–582.
27. *Schaffler A., Muller-Ladner U., Scholmerich J., Büchler* C.: Role of adipose tissue as an inflammatory organ in human diseases. Endocr Rev. 2006; 27: 449-67.
28. *Scheen A.J.*: Pathophysiology of type 2 diabetes. Acta Clin Belg. 2003; 58: 335-41.
29. *Sekar N., Lavoie H.A., Veldhuis J.D.*: Concerted regulation of steroidogenic acute regulatory gene expression by luteinizing hormone and insulin (or insulin-like growth factor I) in primary cultures of porcine granulosa-luteal cells. Endocrinology 2000; 141(11): 3983-3992.
30. *Stamets K., Taylor D.S., Kunselman A., Demers L.M., Pelkman Ch.L., Legro R.S.*: A randomized trial of the effects of two types of short-term hypocaloric diets on weight loss in women with polycystic ovary syndrome. Fertil Steril. 2004; 81 (3): 630-7.
31. *Strychar I.*: Diet in the management of weight loss. *CMAJ* 2006; 174(1): 56–63.
32. *Szczuko M, Pieszak N, Jamioł-Milc D, Stachowska E.*: Dieta proteinowa w świetle zasad racjonalnego żywienia. Analiza składu jadłospisów. [Protein-based diet with respect to the principles of rational nutrition]. Menus analysis. Pomeranian J Life Sci. 2016; 62(2): 40-47.
33. *Szczuko M., Skowronek M., Zapałowska-Chwyć M., Starczewski A.*: Quantitative assessment of nutrition in patients with the polycystic ovary syndrome (PCOS). Rocz Państw Zakł Hig 2016; 67(4): 419-426.
34. *Thomson R.L., Buckley J.D., Noakes M., Clifton P.M., Norman R.J., Brinkworth G.D.*: The effect of a hypocaloric diet with and without exercise training on body composition, cardiometabolic risk profile, and reproductive function in overweight and obese women with polycystic ovary syndrome. J Clin Endocrinol Metab. 2008; 93(9): 3373-3380.
35. *Wertheim K., Sobczyńska-Tomaszewska A., Bal J.*: In search of etiopathogenesis of polycystic ovary syndrome (PCOS). Ginekol Pol. 2007; 78: 626-631.
36. *Wild R.A., Clifton S., Carmina E.*: Lipid levels in polycystic ovary syndrome: systematic review and meta-analysis. Fertil Steril. 2011; 95(3): 1073-1079.
37. *Yancy W.S.J., Olsen M.K., Guyton J.R., Bakst R.P., Westman E.C.*: A low-carbohydrate, ketogenic diet versus a low-fat diet to treat obesity and hyperlipidemia: a randomized, controlled trial. Ann Intern Med. 2004; 140:769-777.
38. *Yildiz B.O., Knochenhauer E.S., Azziz R.*: Impact of Obesity on the Risk for Polycystic Ovary Syndrome. J Clin Endocrinol Metab. 2008; 93(1): 162–168.

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