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Diet quality scores in relation to fatness and nutritional knowledge in women with polycystic ovary syndrome: case–control study

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Abstract

Objective: The purpose of the study was to analyse the dietary habits identified by diet quality scores (DQS) in the scope of body fatness (BF) and nutritional knowledge (NK) of polycystic ovary syndrome (PCOS) women.
Design: Case–control study. The DQS were accessed by Dietary Habits, and Nutrition Beliefs Questionnaire (KomPAN, The Committee of Human Nutrition, Polish Academy of Science) included food frequency consumption of thirty-three food items and was formulated by six diet indexes: Pro-Healthy-Diet-Index (pHDI-10), Non-Healthy-Diet-Index (nHDI-14), High-Glycemic-Diet-Index-7 (hGIDI-7), Low-Glycemic-Diet-Index-4 (lGIDI-4), High-Sugar-Diet-Index-4 (hSDI-4) and High-Saturated-Fats-Diet-Index-8 (hSFDI-8). The BF was analysed by air displacement plethysmography (BodPod, Life Measurement Inc.). NK was assessed by using the twenty-five 'true or false' statements included in the KomPAN questionnaire.
Setting: Poland, Clinical Hospital, Department of Endocrinology, Metabolism, and Internal Diseases.
Participants: The study group included 122 PCOS women and 116 age- and socio-economic status-matched healthy controls (CON) aged 17–44 years.
Results: Higher BF and lower NK in PCOS women *v.* controls were observed. PCOS women had a lower pHDI-10 and LGIDI-4 than CON. There was no relation between NK and DQS in PCOS women. The higher NK in the CON group was associated with increased intensity of pHDI-10 and lower frequency of hSFDI-8 levels.
Conclusions: Pro-healthy DQS and NK of PCOS women in this study were lower than CON. Professional dietary education might improve dietary behaviours and understanding of the necessity of dietary habits modification in this group. A multidisciplinary approach is needed in the treatment of PCOS women.

Keywords
PCOS
Diet quality scores
Nutritional knowledge
Body fatness
Food-frequency questionnaire

Polycystic ovary syndrome (PCOS) is a common female endocrinopathy, recognised as a heterogeneous disorder, characterised by hyperandrogenism, ovulatory dysfunction and polycystic ovary ultrasound image[1]. The prevalence of PCOS ranges between 8 and 13 % around the world and indicates that it has become a major public health issue worldwide[2]. About 50 % of diagnosed women are obese or overweight[3]. Consequently, PCOS women are at increased risk of insulin resistance and metabolic syndrome[4].

The choice of treatment is related to the symptoms such as menstruation abnormalities, androgen excess and infertility[1,5]. One of the main goals of PCOS therapy is to decrease metabolic consequences related to obesity, fatness, insulin resistance and metabolic syndrome. Therefore, it is important to reduce excess of fat mass related to obesity and insulin sensitivity in PCOS women. According to the Androgen Excess Society and the European Society of Endocrinology, PCOS therapy should be based on lifestyle changes, including increased physical activity and dietary modifications concerning the intake of SFA, low Glycaemic Index (GI) foods and weight reduction if necessary[6,7]. Following this, diet quality recommendations and lifestyle modifications for PCOS women should be the prior treatment approach. Despite many studies,

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the optimum and effective diet composition has not yet been identified. A limited number of papers analysing the correlation between diet quality and body composition in PCOS women are available[8,9]. The only confirmed beneficiary strategy for obese PCOS women was concluded by Moran *et al.*[10] and indicated weight loss, without defined diet composition. Other studies suggest instead the role of the particular features of the diet like GI, energy intake reduction, protein and carbohydrates in the management of PCOS[11–18]. Only a few studies analysed the dietary patterns of PCOS women, while their relation to body fatness (BF) had not been studied yet[19,20]. Bearing in mind the fact that diet is the composition of many nutrients, it is increasingly recognised that whole dietary scores are a more important predictor of non-communicable disease risk[21–23]. Moreover, the analysis of overall dietary scores more closely parallels real life, where subjects do not take isolated nutrients but rather as meals consisting of a variety of foods with complex combinations of nutrients which may be interactive or synergistic. The current approach to examine the link between nutrition and diseases recommends moving from single nutrients to dietary patterns, including a group of foods as diet quality scores (DQS). For this reason, the nutritional management of PCOS should be discussed and debated under consideration of overall diet quality and then selected nutrients and their relation to the BF.

Dietary patterns are influenced by social, physiological and economic factors and vary between individuals and populations[24,25]. The status and critical role of nutrition knowledge (NK) have been hypothesised and are still uncertain in public health nutrition. Health abnormalities might be an additional significant factor influencing their dietary choices. As proved in previous studies, nutrition education can cause the change in nutrition behaviours[26], body weight and prevalence of obesity[27,28]. To the best of our knowledge, no studies were investigating whether the NK of PCOS women could be related to their dietary behaviours. Considering that the search of mutual relations between DQS, BF and NK will give a possibility to plan, complementary therapy addresses metabolic abnormalities of PCOS women.

The limited amount of literature in this area provides a basis for further research on the recommended composition of the diet in relation to BF and NK of PCOS women. Therefore, based on the presented studies, it is essential to determine the relation of the DQS, NK and BF in PCOS and compare these with a group of healthy women with similar age and socio-economic status.

Materials and methods

Participants

This case–control study included 122 women with PCOS (PCOS) and 116 age and socio-economically matched healthy controls (CON). Participants were selected and diagnosed in the Department of Endocrinology, Metabolism and Internal Diseases. The patients flow chart is shown in Fig. 1. Women with PCOS were classified according to the Rotterdam criteria[29], which are the most common diagnostic criteria for PCOS. Rotterdam criteria recommend PCOS to be diagnosed when at least two of the following three features were present: (1) oligoovulation; (2) hyperandrogenism (elevated androgen levels: testosterone >2·67 nmol/l, free testosterone >11 pmol/l and/or free androgen index >5·5) or hyperandrogenisation (acne and hirsutism) and/or (3) ultrasonographic findings: the presence of at least twelve follicles in each ovary measuring 2–9 mm in diameter, and/or ovarian volume more than 10 ml. Lack of food allergies and intolerances were inclusion criteria. The CON women were a convenient sample of female volunteers recruited through advertising at the university, local workplaces and public spaces. Inclusion criteria for CON were normal ovulating cycles with no signs of hyperandrogenism. Chronic hepatic, renal and rheumatic diseases, overt hypothyroidism, steroid therapy in the last 3 months and pregnancy were exclusion criteria for both PCOS and CON groups. The use of oral contraceptives was also among exclusion criteria for both groups, due to the inability of PCOS diagnosis while using this type of pharmacotherapy. The same day after endocrinologist appointment, all the participants were directed to the Institute of Human Nutrition and Dietetics, Poznan University of Life Sciences, where the body composition was measured and a dietary interview was performed. The study appointments took place in the mornings, between October 2016 and January 2018.

One hundred seventy-five patients were screened towards PCOS diagnosis between 2016 and 2018, from which 134 patients had positive PCOS diagnosis. One hundred forty-six subjects were self-reported as healthy, but after the screening process, six participants were rejected. During the matching process (described in the Statistics part), twelve participants with PCOS and twenty-four healthy participants were rejected due to age and/or socio-economic status. The BMI of the rejected participants was no different than the study group.

The diet quality scores

The DQS were calculated as dietary indexes, collected with a validated questionnaire (the Dietary Habits and Nutrition Beliefs KomPAN Questionnaire) developed by the Committee of Human Nutrition, Polish Academy of Science[30]. The interview was conducted by a qualified pollster. Closed questions regarding the frequency of consumption of thirty-three food groups were used in the questionnaire. Six food frequency intake categories were used: (1) never, (2) 1–3 times/month, (3) once a week, (4) 2–3 times/week, (5) once a day and (6) a few times during the day. For each food item, the categories of frequency consumption were converted to values

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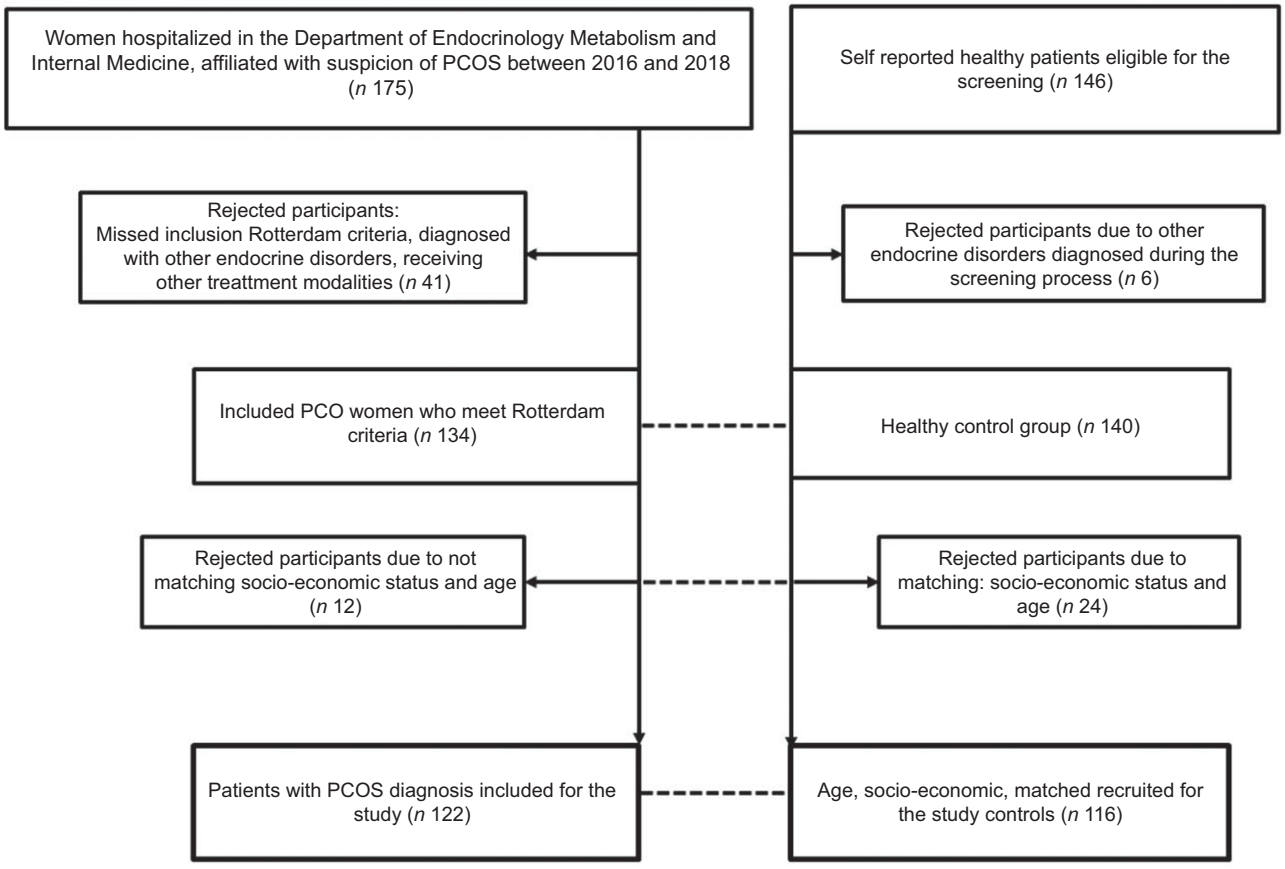

Fig. 1. Study recruitment process

reflecting daily frequency consumption (1) never = 0·00, (2) 1–2 times/month = 0·06, (3) once a week = 0·14, (4) 2–3 times/week = 0·5, (5) once a day = 1 and (6) a few times during the day = 2[31,32]. Conversion rates have been arbitrarily accepted by literature analysis and the authors' own experience[33]. The description of food frequency intake was undertaken by using the diet indexes characterising the intensity of food frequency intake of chosen groups of products widely known as healthy, unhealthy, with a high- and low-GI, high content of simple sugars and saturated fats. To evaluate overall diet quality, a pro-Healthy-Diet-Index (pHDI-10) and a non-Healthy-Diet-Index (nHDI-14) scores were established based on previous knowledge and other validated studies[34]. Due to multiple reports on its effects in PCOS management, high- and low-GI foods as well as foods with high saturated fats and high simple sugar were analysed[10,11,35]. To elucidate dietary intake of high- and low-GI foods, high-sugar, and high saturated fat dietary sources, the four novum DQS were created by the authors based on the previously validated scores (pHDI-10, n-HDI-14) (Table 2). Each index was designed and calculated based on the same conversion formula as previously validated[33]:

$$Diet\ Quality\ Index = \frac{100\% * \sum A}{\sum B}\ [\%]$$

where A is the sum of the reported daily intake of all items listed in specific food groups (e.g. low GI, see Table 2), for example, $\Sigma = 0 + 0{\cdot}14 + 0{\cdot}06 + 0{\cdot}5$. B is the sum of the maximum possible to report daily intake of the same (low GI) foods, determined for one product as 2 (e.g. $\Sigma = 2 + 2 + 2 + 2$).

All dietary scores were created *a priori* by summing the consumption frequencies (times/d) of the following food items: the pHDI – dairy products, fish, vegetables, fruit; the nHDI – fast food, sweetened soft drinks, energy drinks, and sweets, both already validated[33]. For this study, the high-Glycaemic-Diet-Index-7 (hGIDI-7), low-Glycaemic-Diet-Index-4 (LGIDI-4), high-Sugar-Diet-Index-4 (hSDI-4) and the high-saturated-fats-Diet-Index-8 (hSFDI-8) indexes were designed. Groups of food products classified in individual diet indexes are presented in Table 2. The consumption levels of the food groups (indexes) were classified on a percentage scale. Each DQS was expressed in % points and was categorised as follows: low (0–33·32 % points), moderate (33·33–66·65 % points) and high (66·66–100 % points) intensity of consumption of selected food groups. For example, the calculation for low-Glycaemic-Diet-Index-4 (LGIDI-4) was: lGIDI-4 = 100 %*0·7/8 = 8·75 %. There was a low intensity of consumption of low GI foods in the studied group.

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Body fatness

The subject's BF was assessed by the air displacement plethysmography method using BodPod (Life Measurement Inc.). During the measurement, all the subjects wore swimming suits and swimming caps; they fasted for 2 h before the analysis[36]. The measurements were taken in morning hours. The reference values for the body fat (BF) percentage were accepted from the literature[37] in the three ranges: normal (below 30 %), above normal (30–36 %) and high risk (above 36 %). The basic anthropometric measurements were also taken: body mass (kg), height (cm), waist and hip circumference (cm).

Nutrition knowledge

The nutrition beliefs and knowledge of the studied groups were determined by using the validated KomPAN questionnaire[33]. It included the twenty-five statements and assessments expressed as 'truth', 'false' and 'hard to say'. For each correct answer, the respondent received 1 point, and for an incorrect answer or 'hard to say', 0 point. Points were summed up for each respondent (range 0 to 25 points). The respondents were divided into three nutrition knowledge categories: insufficient (0–8 points), sufficient (9–16 points) and good (17–25 points).

Physical activity

To assess physical activity, the short version of the international physical activity questionnaire was used[38].

Statistics

To calculate the sample size, the Sample Size Calculator Clinical Calc (ClinCalc, LLC) was used[39]. The anticipated means of the pHDI-10 score were set as 27 ± 15 (low score) and 34 (high score). The minimum number of subjects for adequate study power was calculated as 119 for each independent group with the enrolment ratio set at 1, type I error at 0·05 and power 95 %.

To achieve comparability between the study groups (PCOS *v.* CON), propensity score 1:1 matching was performed, in which patients in the PCOS group were matched with counterparts in the CON group according to age and socio-economic status. The subjects were matched according to the closest distance with the replacement of the matched control subject[40]. The normality of the distribution data was verified with the Shapiro–Wilk test. The logistic regression was used to determine the OR for DQS and body fat by nutrition knowledge. Differences in nutritional status and frequency intake were calculated using the *t* test of two independent samples. For non-normal distribution data, the Mann–Whitney *U* test was used. Values are presented as mean and median. The 95 % CI was set. A *P* value of <0·05 was considered to be statistically significant. The statistical analysis was carried out using Statistica 13·1 software (Dell Inc. 2016).

Results

As depicted in Table 1, the general characteristics show that most of the women participated in the study lived in cities with more than 20 000 residents, declared an average economic situation, had higher education level and lived in 1–4 person households. In the PCOS group, more women smoked cigarettes. As shown in Table 1, over 40 % of women with PCOS were overweight or obese and presented a higher BF.

Table 3 shows the significant anthropometric differences between the PCOS and CON groups. The women with PCOS had significantly higher body fat and BMI. The waist:height ratio was significantly higher in comparison with the CON group. Women with PCOS declared less intense physical activity and more sitting time than the control group. Ninety-one percentage of the PCOS group were diagnosed with hyperandrogenism, 76 % had oligoovulation, 91 % irregular menstruation, 13 % hyperlipidaemia and 34 % insulin resistance.

As shown in Table 4, both groups presented low intensity of consumption of foods perceived as generally healthy. The PCOS group had a significantly lower frequency intake of pro-healthy foods (pHDI-10) and low GI foods (LGIDI-4) than the CON group. There was a tendency in a higher frequency of high-sugar product (hSFDI-8) intake in the PCOS group than the CON group. PCOS had a lower intake of fruits, vegetables and cottage cheese, what has been shown in detailed components of the indexes included in the online supplementary material, Supplementary Table 6. To ensure that the frequency of eating is not only related to the higher body mass of PCOS women, we stratified the PCOS and CON groups by BMI: 1. BMI < 25 and BMI ≥ 25 (PCOS) and 2. BMI < 30 and BMI ≥ 30 (CON). After performing a Mann–Whitney *U* test in the CON group, the PCOS group and combined, we did not find any statistical differences between the DQS stratified by BMI. The subjects from the PCOS group had lower average (sufficient level) NK compared with the CON group (at a good level) according to the validation protocol[33], as shown in Table 4.

CON women with at least a good level of NK were more than two times likely to have a high intensity of intake of pro-healthy foods (pHDI-10) and had less than a half likely to have a high intensity of intake of saturated fat dietary sources (hSFDI-8) (Table 5). There was also a tendency in controls with at least good knowledge to have a high intensity of consumption of low GI foods (lGIDI-4) and low intensity of high GI foods. These results did not repeat in the PCOS group.

Discussion

Our study revealed the dietary habits identified by DQS in the scope of fatness and NK of PCOS women. To the best of

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Table 1. Sample characteristics between women with polycystic ovary syndrome (PCOS) and control group

Variables†	PCOS (*n* 122)	PCOS (%)	CON (*n* 116)	CON (%)	*P*‡
Age (years)					0·48
≤25	63	52	51	44	
26–29	33	27	27	23	
30–35	18	15	23	20	
36–45	8	7	15	13	
BMI (kg/m^2)					0·00*
<18·5 underweight	3	3	10	9	
18·5–24·9 normal	65	53	85	73	
25·0–29·9 overweight	28	23	12	10	
≥30·0 obesity	26	21	10	9	
BF%					0·00*
≤30 normal	36	30	55	48	
30–36 increased	25	20	21	18	
≥36 increased risk	61	50	39	34	
Place of residence					0·69
Village	26	21	26	22	
City < 20 000 residents	9	7	8	7	
City 20 –100 000 residents	27	22	19	16	
City > 100 000 residents	60	49	63	54	
Self-reported economic situation					0·91
"Below average"	3	2	3	3	
"Average"	85	70	81	70	
"Higher than average"	31	25	30	26	
Education					0·21
Basic	5	4	0	0	
Vocational	1	1	1	1	
Middle	41	34	47	40	
Higher	72	59	64	55	
Number of people in the household					0·89
1 or 2	49	40	40	34	
3 or 4	55	45	56	48	
5 and over	18	15	20	17	
Employment					0·10
No, I am on retirement/pension	2	2	3	3	
No, I am on maternity leave, parental leave, unemployed, staying at home	25	20	33	28	
Yes, but a temporary job	23	19	14	12	
Yes, I am permanently employed	70	57	57	49	
Smoking cigarettes					0·01*
Yes	16	13	5	4	
No	106	87	111	96	
Physical activity (MET-minute/week)§					0·49
Insufficient	63	52	58	49	
Sufficient	22	18	27	23	
High	14	11	11	9	
Clinical characteristics					0·00*
Hyperandrogenism	111	91	0	0	
Oligovulation	93	76	0	0	
Irregular cycles	111	91	0	0	
Hyperlipidaemia	16	13	0	0	
Insulin resistance	42	34	0	0	

*$P < 0·05$.
†Variables categorised into clases (as percentage and number of subjects in presented category, e.g. age ≤ 24·9).
‡Results from the χ^2 test.
§Physical activity was categorised according to the manual of a short version of International Physical Activity Questionnaire (IPAQ-SF)[38].

our knowledge, this research is the first study to identify using the *a priori* approach, the dietary intake in PCOS women through integrated nutrition quality scores covering groups of food items. Based on the frequency intake of thirty-three food groups, DQS were grouped and categorised according to consumed food products: pro-healthy, non-healthy, low- and high-GI, a high simple sugar, high SFA. PCOS women, in comparison with CON subjects, presented lower intensity of consumption of foods recommended as 'generally healthy' (pHDI-10, Pro-Healthy-Diet-Index-10) and foods characterised by low GI (lGDI-4, Low-Glycemic-Diet-Index-4). We found no relation between DQS, nutrition knowledge and body fat percentage among PCOS women, which was apparent in the healthy control group. Concurrently, we observed a higher body fat and lower nutrition knowledge in the PCOS group.

The first dietary characteristics in PCOS women we present were the low-intensity consumption of foods perceived as healthy. It was found that fruits, vegetables and cottage cheese intake were the main factors involved in

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Table 2. Characteristics of dietary indexes

Dietary indexes	Groups of products
pHDI-10 (Pro-Healthy-Diet-Index-10)	(1) Whole-wheat bread; (2) whole-wheat cereals, oatmeal, whole-wheat pasta; (3) milk; (4) fermented milk drinks; (5) cottage cheese; (6) white meat; (7) fish; (8) dishes with legumes; (9) fruits; (10) vegetables
nHDI-14 (Non-Healthy-Diet-Index-14)	(1) White bread; (2) white rice, pasta, fine-ground groats; (3) fast food; (4) fried dishes; (5) butter; (6) lard; (7) cheese; (8) cold meats, smoked sausages, hot-dogs; (9) red meat dishes; (10) sweets; (11)tinned meats; (12) sweetened carbonated and non-carbonated drinks; (13) energy drinks; (14) alcoholic beverages
hGIDI-7 (High-Glycemic-Diet-Index-7)	(1) White bread; (2) white rice, pasta, fine-ground groats; (3) sweets; (4) sweetened carbonated and non-carbonated drinks; (5) juices; (6) sweetened hot drinks; (7) fruits
lGIDI-4 (low-Glycaemic-Diet-Index-4; lGIDI-4 = 100 % × 0·7/8 = 8·75 %. The consumption of low GI foods in diet low intensity.)	(1) Whole-wheat bread; (2) whole-wheat cereals, oatmeal, whole-wheat pasta; (3) dishes with legumes; (4) vegetables
hSDI-4 (High-Sugar-Diet-Index-4)	(1) Sweets; (2) sweetened carbonated and non-carbonated drinks; (3) sweetened hot drinks; (4) juices
hSFDI-8 (High-Saturated-Fats-Diet-Index-8)	(1) butter; (2) lard; (3) red meat dishes; (4) cold meats, smoked sausages, hot-dogs; (5) tinned meat; (6) cheese; (7) fried dishes; (8) fast food

Table 3. Anthropometrics, physical exercise and body composition measurements between polycystic ovary syndrome (PCOS) and control group

	PCOS (*n* 122)		CON (*n* 116)		
	Mean	SD	Mean	SD	*P*†
Age (years)	27	6	26	5	0·39
Body mass (kg)	72·5	17·5	63·8	13·7	0·00*
BMI (kg/m^2)	26·2	6·2	22·8	4·6	0·00*
BF (%)	36·5	9·7	31·1	8·6	0·00*
Waist (cm)	82·7	14·3	75·7	10·7	0·00*
WHtR (–)	0·50	0·08	0·45	0·06	0·00*
High-intensity physical activity‡	1892	9215	6855	21 629	0·03*
Medium-intensity physical activity‡	2168	6988	2995	9119	0·46
Walking‡	2637	7710	2990	7543	0·73
Sitting‡	2205	2863	1535	894	0·02*

WHtR, waist:height ratio.
†Level of significance for the comparison of means between groups: *$P < 0·05$.
‡MET-minute/week.

Table 4. Diet indexes and nutritional knowledge in polycystic ovary syndrome (PCOS) and CON women

	PCOS (*n* 122)					CON (*n* 116)					
	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	*P*†
pHDI-10 (%)	23·5	10·0	23·0	6·0	51·0	26·1	10·0	26·0	6·0	49·0	0·04*
nHDI-14 (%)	13·0	7·2	11·0	0·6	37·8	13·4	8·2	11·1	1·2	38·0	0·94
hGIDI-7 (%)	16·1	11·2	22·0	13	0·0	16·3	11·8	13·0	0·0	87·0	0·82
hSDI-4 (%)	14·9	13·5	11·1	0·0	75·0	13·5	13·9	9·2	0·0	100·0	0·08
hSFDI-8 (%)	11·9	7·6	10·9	0·0	45·0	12·1	7·7	11·1	0·0	32·0	0·97
lGIDI-4 (%)	27·5	13·1	26·3	3·0	57·0	30·5	12·7	28·5	4·5	62·0	0·02*
NK (points)	15·0	4·9	16·0	4·0	23·0	16·7	5·9	18·0	0·0	25·00	0·01*

pHDI-10, Pro-Healthy-Diet-Index-10; nHDI-14, Non-Healthy-Diet-Index-14; hGIDI-7, High-Glycemic-Diet-Index-7; hSDI-4, High-Sugar-Diet-Index-4; hSFDI-8, High-Saturated-Fats-Diet-Index-8; lGIDI-4, Low-Glycemic-Diet-Index-4; NK, nutrition knowledge.
†Level of significance for the comparison of means between groups: *$P < 0·05$.

lowering pHDI-10. Other characteristics were the low intensity of consumption of low GI foods, recommended for consumption for PCOS, and included whole-wheat bread, whole-wheat cereals, oatmeal, whole-wheat pasta, dishes with legumes and vegetables. The vegetables were the most significant group to differentiate PCOS and controls. In spite of above food groups, PCOS women declared a higher intensity (30 % more than control) of consumption of fast food. Our results suggest that PCOS women were prone to a less healthy lifestyle; they were smokers more

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Table 5. OR (95 % CI) for diet quality scores and body fat by nutrition knowledge in polycystic ovary syndrome (PCOS) women and healthy control group

	PCOS					CON				
Dietary scores	%	*n*	OR	95 % CI	*P*	%	*n*	OR	95 % CI	*P*
Body fat ≥36%†										
Nutrition knowledge ≥ good§	16	19	0·92	0·4, 2·0	0·85	9	11	0·58	0·2, 1·5	0·26
pHDI-10 ≥ high-intensity‡ (Pro-Healthy-Diet-Index-10)										
Nutrition knowledge ≥ good§	8	10	0·84	0·3, 2·0	0·70	27	32	2·25	1·0, 4·9	0·03*
nHDI-14 ≥ high-intensity (Non-Healthy-Diet-Index-14)										
Nutrition knowledge ≥ good§	8	10	0·64	0·3, 1·5	0·31	16	19	0·49	0·2, 1·0	0·07
lGIDI-4 ≥ high-intensity (Low-Glycemic-Diet-Index-4)										
Nutrition knowledge ≥ good§	11	13	1·16	0·5, 2·6	0·72	27	31	1·90	0·9, 4·2	0·09
HGIDI-7 ≥ high-intensity (High-Glycemic-Diet-Index-7)										
Nutrition knowledge ≥ good§	9	11	0·69	0·3, 1·6	0·39	16	19	0·54	0·2, 1·1	0·10
hSDI-4 ≥ high-intensity (High-Sugar-Diet-Index-4)										
Nutrition knowledge ≥ good§	10	12	0·60	0·3, 1·3	0·22	15	18	0·58	0·3, 1·3	0·17
hSFDI-8 ≥ high-intensity (High-Saturated-Fats-Diet-Index-8)										
Nutrition knowledge ≥ good§	9	11	0·77	0·3, 1·8	0·54	16	19	0·46	0·2, 1·0	0·05*

Level of significance for the comparison of means between groups: *$P < 0·05$.
†Body fat content categories according to Jeukendrup and Michael[37].
‡High intensity of frequency intake refers to upper tertile of each of index.
§Nutrition knowledge referred to as good according to the validated questionnaire manual.

often than CON and engaged in less intense physical activity but were sitting more. Such picture of studied PCOS was supplemented by 20 % and 22 % lower consumption of fruit and vegetables in this group. This tendency was also observed by Shishehgar *et al.*[41]. According to the current nutrition guidelines for the general population, the majority of food groups classified in the healthy and low glycaemic intake index (pHDI-10 and lGIDI-4) should be consumed at least several times a day. Food products classified in the nonhealthy dietary index (nHDI-14) and high GI (hGIDI-7) (white bread, white rice, plain pasta or cereal, fast food, butter, lard, cheese, sausages, red meat, sweets, canned meat, sweetened carbonated and non-carbonated drinks, energy drinks and alcoholic beverages) should be consumed in the smallest possible amounts. Dietary intake profile of our PCOS women was contrary to the recommendation of increasing the consumption of low GI products. According to Androgen Excess Society recommendations, it is necessary to increase the intake of low GI products, including fruit and vegetables[6]. This approach may help to improve the effects of treatment associated with insulin resistance, which is supported by multiple intervention studies[13,15–17].

In our study, the relation of DQS to BF was sought as well. We hypothesised that the diet quality, along with hormonal abnormalities, like hyperandrogemia, might support increased BF. The etiopathogenesis of obesity in PCOS has not yet been exactly explained. The hyperandrogenaemia, as was mentioned in other studies, could enhance the visceral obesity of PCOS women[42,43]. Having in mind, the fact of hormonal abnormalities in PCOS; we had a look at possible relations of BF to DQS. We could not find any relationship there. Despite this, it is necessary to underline that the comparison of PCOS and CON groups revealed that nonetheless of matching procedure for age and socio-economic status, the BF of PCOS women was higher than healthy participants. The study group had a similar body composition to subjects in other studies, further supporting the data that half of PCOS women are overweight or obese[44].

Considering the lower diet quality in PCOS, it is essential to find the reasons standing behind it. Keeping this in mind, we analysed the nutrition knowledge. It has been shown that knowledge influences dietary behaviours, particularly the intake of fruits and vegetables which, in turn, stimulates dietary patterns and determines BF[45]. Our study reveals that women with PCOS presented lower NK than controls. In contrast, the literature suggests that PCOS women show higher knowledge and motivation to implement preventive health strategies, which is related to the economic situation and education level[28,46–49]. Some authors suggest that PCOS women seem to be interested in broadening their knowledge and practising healthy behaviours which are related to DQS[50]. It is possible that women from our study were not engaged in dietary consultations but used fad diets, internet forums and were guided by advertising in their dietary choices. Additionally, it must be underlined that we have been looking at relations between NK and BF in the studied group. The current results in PCOS did not confirm the expected relationships. Such a relationship was evident in healthy controls, where the intake of prohealthy and saturated fat groups of products was driven by NK. This difference between PCOS and CON might suggest additional factors like hormonal abnormalities influencing BF in PCOS, lower motivation and dietary adherence. Additionally, such differences could be explained by nutrition knowledge or related to psychological state, which has been hypothesised by other authors and was not analysed in our study[51].

Although the research has reached its aims, it may have some limitations. First of all, the retrospective setting of the

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study. We are not sure if women already have been changing their nutrition behaviours. This problem is partially solved by the time of the diagnosis. Women in our study were diagnosed for the first time with PCOS. However, the nature of symptoms of this disorder could cause the change in their health behaviours before the study commenced. Due to this reason, and higher body weight, there is a possibility that the women involved in the study could have under-reported their intake, especially concerning unhealthy products and simple sugar sources[52].

Second, even though the present study determined the dietary scores of 238 women by the frequency of intake of thirty-three foods, the portion size was not determined. This could have prevented an accurate assessment of the dietary nutrient intake. A lack of recording of portion sizes could explain the absence of statistical differences between the intake of non-healthy, high GI, saturated fats and dietary sugar sources. Furthermore, we did not analyse week and weekend fluctuations in dietary intake, as it was proven in previous studies, where women generally report large fluctuations in the intake of sugar and other nutrients[53]. Moreover, underestimation may be contributed to the compulsive eating of products generally considered unhealthy, which is not possible to observe with the FFQ[54].

Third, the study did not consider the seasonality of food consumption. As the authors of previous studiesshowed, DQS would have been more precise and differentiated if the seasonality of consumption had been considered in the frequency of intake[55].

Fourth, the tool used to analyse the frequency of intake was validated on healthy subjects. Verification questions concerning frequency consumption were collected, analysed and revealed high repeatability of collected data. Another limitation was the size of the study sample, which restricted the use of statistical methods recommended for dietary pattern evaluation[56,57].

Finally, considering the role of body fat distribution and cardiometabolic risk in PCOS women, it would be valuable to assess the androidal and gynoidal body fat distribution. In this study, despite the use of the 'gold standard', plethysmography, only total BF was assessed. Additionally, the fact that hormonal disturbances potentially influenced fat distribution should be taken into account.

Conclusions

In conclusion, our results pointed to the role of multidisciplinary therapy including dietary behaviours in PCOS women. We found differences between PCOS women and healthy controls in lower DQS related to generally healthy foods and low GI foods. PCOS women presented lower NK. The professional dietary education and improving the NK of PCOS women could affect the diet quality and increase the presence of hygienic lifestyle factors. The complementary treatment of PCOS, to ensure the optimal improvements in the disease endpoints, should be implemented after PCOS diagnosis.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980020001755

References

1. Sirmans SM & Pate KA (2013) Epidemiology, diagnosis, and management of polycystic ovary syndrome. *Clin Epidemiol* **6**, 1–13.
2. Bozdag G, Mumusoglu S, Zengin D *et al.* (2016) The prevalence and phenotypic features of polycystic ovary syndrome: a systematic review and meta-analysis. *Hum Reprod* **31**, 2841–2855.
3. Azziz R, Woods KS, Reyna R *et al.* (2004) The prevalence and features of the polycystic ovary syndrome in an unselected population. *J Clin Endocrinol Metab* **89**, 2745–2749.

4. Pasquali R (2018) Metabolic syndrome in polycystic ovary syndrome. *Front Horm Res* **49**, 114–130.
5. Knochenhauer ES, Key TJ, Kahsar-Miller M *et al.* (1998) Prevalence of the polycystic ovary syndrome in unselected black and white women of the Southeastern United States: a prospective study. *J Clin Endocrinol Metab* **83**, 3078–3082.
6. Conway G, Dewailly D, Diamanti-Kandarakis E *et al.* (2014) The polycystic ovary syndrome: a position statement. *Eur J Endocrinol* **171**, P1–P29.
7. Salley KES, Wickham EP, Cheang KI *et al.* (2007) Position statement: glucose intolerance in polycystic ovary syndrome: a position statement of the androgen excess society. *J Clin Endocrinol Metab* **92**, 4546–4556.
8. Pasquali R, Gambineri A, Biscotti D *et al.* (2000) Effect of long-term treatment with metformin added to hypocaloric diet on body composition, fat distribution, and androgen and insulin levels in abdominally obese women with and without the polycystic ovary syndrome. *J Clin Endocrinol Metab* **85**, 2767–2774.
9. Cunha NB, da, Ribeiro CT, Silva CM *et al.* (2018) Dietary intake, body composition and metabolic parameters in women with polycystic ovary syndrome. *Clin Nutr* **38**, 2342–2348.
10. Moran LJ, Ko H, Misso M *et al.* (2013) Dietary composition in the treatment of polycystic ovary syndrome: a systematic review to inform evidence-based guidelines. *J Acad Nutr Diet* **113**, 520–545.
11. Graff SK, Mario FM, Magalhães JA *et al.* (2017) Saturated fat intake is related to heart rate variability in women with polycystic ovary syndrome. *Ann Nutr Metab* **71**, 224–233.
12. Eslamian G, Baghestani A-R, Eghtesad S *et al.* (2017) Dietary carbohydrate composition is associated with polycystic ovary syndrome: a case–control study. *J Hum Nutr Diet* **30**, 90–97.
13. Galletly C, Moran L, Noakes M *et al.* (2007) Psychological benefits of a high-protein, low-carbohydrate diet in obese women with polycystic ovary syndrome: a pilot study. *Appetite* **49**, 590–593.
14. Zhang J, Liu Y, Liu X *et al.* (2015) High intake of energy and fat in Southwest Chinese women with PCOS: a population-based case–control study. *PLoS One* **10**, e0127094.
15. Phy JL, Pohlmeier AM, Cooper JA *et al.* (2015) Low starch/low dairy diet results in successful treatment of obesity and co-morbidities linked to polycystic ovary syndrome (PCOS) HHS public access. *J Obes Weight Loss Ther* **5**, 259.
16. Marsh KA, Steinbeck KS, Atkinson FS *et al.* (2010) Effect of a low glycemic index compared with a conventional healthy diet on polycystic ovary syndrome. *Am J Clin Nutr* **92**, 83–92.
17. Sordia-Hernandez LH, Rodriguez PA, Rodriguez DS *et al.* (2016) Effect of a low glycemic diet in patients with polycystic ovary syndrome and anovulation: a randomized controlled trial. *Clin Exp Obstet Gynecol* **43**, 555–559.
18. Milewicz A, Kudła M, Spaczyński RZ *et al.* (2018) The polycystic ovary syndrome: a position statement from the Polish Society of Endocrinology, the Polish Society of Gynaecologists and Obstetricians, and the Polish Society of Gynaecological Endocrinology. *Endokrynol Pol* **69**, 328–336.
19. Shahdadian F, Ghiasvand R, Abbasi B *et al.* (2018) Association between major dietary patterns and polycystic ovary syndrome: evidence from a case–control study. *Appl Physiol Nutr Metab* **44**, 52–58.
20. Huijgen NA, Louwers YV, Willemsen SP *et al.* (2017) Dietary patterns and the phenotype of polycystic ovary syndrome: the chance of ongoing pregnancy. *Reprod Biomed Online* **34**, 668–676.
21. Reedy J, Krebs-Smith SM, Miller PE *et al.* (2014) Higher diet qwuality is associated with decreased risk of all-cause, cardiovascular disease, and cancer mortality among older adults. *J Nutr* **144**, 881–889.
22. Schwingshackl L, Bogensberger B & Hoffmann G (2018) Diet quality as assessed by the healthy eating index, alternate healthy eating index, dietary approaches to stop hypertension score, and health outcomes: an updated systematic review and meta-analysis of cohort studies. *J Acad Nutr Diet* **118**, 74–100.e11.
23. Milajerdi A, Namazi N, Larijani B *et al.* (2018) The association of dietary quality indices and cancer mortality: a systematic review and meta-analysis of cohort studies. *Nutr Cancer* **70**, 1091–1105.
24. Birkenhead KL & Slater G (2015) A review of factors influencing athletes' food choices. *Sport Med* **45**, 1511–1522.
25. Kabir A, Miah S & Islam A (2018) Factors influencing eating behavior and dietary intake among resident students in a public university in Bangladesh: a qualitative study. *PLoS One* **13**, e0198801.
26. Hamulka J, Wadolowska L, Hoffmann M *et al.* (2018) Effect of an education program on nutrition knowledge, attitudes toward nutrition, diet quality, lifestyle, and body composition in polish teenagers: the ABC of healthy eating project: design, protocol, and methodology. *Nutrients* **10**, 1439.
27. Valmorbida JL, Goulart MR, Busnello FM *et al.* (2017) Nutritional knowledge and body mass index: a cross-sectional study. *Rev Assoc Med Bras* **63**, 736–740.
28. Bonaccio M, Di Castelnuovo A, Costanzo S *et al.* (2013) Nutrition knowledge is associated with higher adherence to Mediterranean diet and lower prevalence of obesity: results from the Moli-sani study. *Appetite* **68**, 139–146.
29. The Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group (2004) Revised 2003 consensus on diagnostic criteria and long-term health risks related to polycystic ovary syndrome. *Fertil Steril* **81**, 19–25.
30. Jeżewska-Zychowicz M, Gawęcki J, Wądołowska L *et al.* (2018) The Dietary Habits and Nutrition Beliefs Questionnaire for people 15–65 s old, ver. 1.1. – interviewer administered questionnaire. Chapter 1. In *Dietary Habits and Nutrition Beliefs Questionnaire and the Manual for Developing of Nutritional Data*, pp. 3–20 [J Gawecki, editor]. Olsztyn: The Committee of Human Nutrition, Polish Academy of Sciences. http://www.knozc.pan.pl (accessed August 2019).
31. Wadolowska L, Ulewicz N, Sobas K *et al.* (2018) Dairy-related dietary patterns, dietary calcium, body weight and composition: a study of obesity in polish mothers and daughters, the MODAF project. *Nutrients* **10**, 90.
32. Wadolowska L, Hamulka J, Kowalkowska J *et al.* (2019) Changes in sedentary and active lifestyle, diet quality and body composition nine months after an education program in polish students aged 11–12 years: report from the ABC of healthy eating study. *Nutrients* **11**, 331.
33. Kowalkowska J, Wadolowska L, Czarnocinska J *et al.* (2018) Reproducibility of a Questionnaire for Dietary Habits, Lifestyle and Nutrition Knowledge Assessment (KomPAN) in polish adolescents and adults. *Nutrients* **1**, E1845.
34. Gawęcki J (editor) (2018) *Dietary Habits And Nutrition Beliefs Questionnaire and the Manual for Developing Nutritional Data*. Olsztyn, Poland: Committee of Human Nutrition Science, Polish Academy of Sciences.
35. Graff SK, Mário FM, Alves BC *et al.* (2013) Dietary glycemic index is associated with less favorable anthropometric and metabolic profiles in polycystic ovary syndrome women with different phenotypes. *Fertil Steril* **100**, 1081–1088.
36. Biaggi RR, Vollman MW, Nies MA *et al.* (1999) Comparison of air-displacement plethysmography with hydrostatic weighing and bioelectrical impedance analysis for the assessment of body composition in healthy adults. *Am J Clin Nutr* **69**, 898–903.
37. Jeukendrup A & Michael G (2010) *Sport Nutrition*, 2nd ed. Champaign, IL, USA: Human Kinetics.
38. Lee PH, Macfarlane DJ, Lam TH *et al.* (2011) Validity of the international physical activity questionnaire short form (IPAQ-SF): a systematic review. *Int J Behav Nutr Phys Act* **8**, 115.

https://doi.org/10.1017/S1368980020001755 Published online by Cambridge University Press

39. Sean P. Kane Sample size calculator. https://clincalc.com/ (accessed January 2019).
40. Deb S, Austin PC, Tu JV *et al.* (2016) A review of propensity-score methods and their use in cardiovascular research. *Can J Cardiol* **32**, 259–265.
41. Shishehgar F, Ramezani Tehrani F, Mirmiran P *et al.* (2016) Comparison of dietary intake between polycystic ovary syndrome women and controls. *Glob J Health Sci* **1**, 54801.
42. Allan CA, Strauss BJG, Burger HG *et al.* (2008) Testosterone therapy prevents gain in visceral adipose tissue and loss of skeletal muscle in nonobese aging men. *J Clin Endocrinol Metab* **93**, 139–146.
43. Mårin P, Holmtäng S, Gustafsson C *et al.* (1993) Androgen treatment of abdominally obese men. *Obes Res* **1**, 245–251.
44. Van Hooff MHA, Voorhorst FJ, Kaptein MBH *et al.* (1999) Endocrine features of polycystic ovary syndrome in a random population sample of 14–16 year old adolescents. *Hum Reprod* **14**, 2223–2239.
45. Spronk I, Kullen C, Burdon C *et al.* (2014) Relationship between nutrition knowledge and dietary intake. *Br J Nutr* **111**, 1713–1726.
46. Beydoun MA & Wang Y (2008) Do nutrition knowledge and beliefs modify the association of socio-economic factors and diet quality among US adults? *Prev Med (Baltim)* **46**, 145–153.
47. Moran L, Grieger J, Mishra G *et al.* (2015) The association of a Mediterranean-style diet pattern with polycystic ovary syndrome status in a community cohort study. *Nutrients* **7**, 8553–8564.
48. Hamulka J, Wawrzyniak A & Sulich A (2012) The assessment of beta-carotene, lycopene and lutein intake selected group of adults: Ocena spozycia beta-karotenu, likopenu i luteiny w wybranej grupie osób dorosłych. *Rocz Państwowego Zakładu Hig* **63**, 179–186.
49. Sobas K, Wadolowska L, Slowinska MA *et al.* (2015) Like mother, like daughter? Dietary and non-dietary bone fracture risk factors in mothers and their daughters. *Iran J Public Health* **44**, 939–952.
50. Marijn Stok F, Renner B, Allan J *et al.* (2018) Dietary behavior: an interdisciplinary conceptual analysis and taxonomy. *Front Psychol* **9**, 1689.
51. Kitzinger C & Willmott J (2002) 'The thief of womanhood': women's experience of polycystic ovarian syndrome. *Soc Sci Med* **54**, 349–361.
52. Wardle J, Haase AM, Steptoe A *et al.* (2004) Gender differences in food choice: the contribution of health beliefs and dieting. *Ann Behav Med* **27**, 107–116.
53. Czlapka-Matyasik M, Lonnie M, Wadolowska L *et al.* (2018) "Cutting Down on Sugar" by non-dieting young women: an impact on diet quality on weekdays and the weekend. *Nutrients* **10**, 1463.
54. Waling MU & Larsson CL (2009) Energy intake of Swedish overweight and obese children is underestimated using a diet history interview. *J Nutr* **139**, 522–527.
55. Czlapka-Matyasik M & Ast K (2014) Total antioxidant capacity and its dietary sources and seasonal variability in diets of women with different physical activity levels. *Polish J Food Nutr Sci* **64**, 267–276.
56. Garcia-Larsen V, Morton V, Norat T *et al.* (2019) Dietary patterns derived from principal component analysis (PCA) and risk of colorectal cancer: a systematic review and meta-analysis. *Eur J Clin Nutr* **73**, 366–386.
57. Cespedes EM & Hu FB (2015) Dietary patterns: from nutritional epidemiologic analysis to national guidelines. *Am J Clin Nutr* **101**, 899–900.

https://doi.org/10.1017/S1368980020001755 Published online by Cambridge University Press