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The association between meat consumption and polycystic ovary syndrome in Iranian women: a case–control study

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Abstract

Background In light of the observed association between nutritional factors and polycystic ovary syndrome (PCOS) in recent decades, the present study was conducted to investigate the association between the consumption of various types of meat and PCOS in Iranian women.

Material and methods This frequency-matched case–control study included 108 women with newly diagnosed PCOS and 108 age and body-mass-index-matched women without PCOS, as a control group, who were referred to the Yazd Diabetes Clinic and Khatam Clinic between January 2018 and March 2019. The validated 178-item food frequency questionnaire was used to assess the usual dietary intake. Logistic regression analysis was used to estimate the association between meat consumption and PCOS.

Results The findings of this study showed, the individuals in the third tertile of red meat intake, had higher odds of PCOS in the crude model (Odds Ratio (OR) = 4.29; 95% Confidence Interval (CI), 2.13–8.64; *P*-value = 0.001) compared with those in the first tertile. These results remained significant after adjustments for energy intake, marital status, physical activity, education, pregnancy history and chronic disease history (OR = 3.87; 95% CI, 1.78–8.40; *P*-value = 0.001). Higher consumption of red meat increased the risk of PCOS by 3.87 times. Furthermore, higher consumption of processed meats increased the risk of PCOS by 2.15 times (OR = 2.15; 95% CI, 1.05–4.39; *P*-value and trend = 0.035). We did not find an association between other types of meat consumption and PCOS.

Conclusion The results of the present study showed that a higher consumption of red and processed meat is associated with a higher risk of PCOS, whereas no significant correlation was found between the consumption of poultry, fish, and organ meat and PCOS. However, more studies are needed to support these findings in the future.

Keywords Polycystic ovary syndrome, Red meat consumption, White meat consumption, Processed meats consumption

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Introduction

Polycystic ovary syndrome (PCOS) which is known as a common endocrine disorder [1], characterized by elevated androgen levels, impaired ovulation and/or observation of cysts in one or both ovaries, and is a disease with hereditary transmission capacity [2]. According to the Rotterdam criteria, the overall prevalence is approximately 10% [3], and among Iranian women, it is estimated at 19.5% [4]. While PCOS primarily affects reproductive health and infertility [5], it is associated with several significant complications, including obesity, insulin resistance (IR), type 2 diabetes, metabolic syndrome, and cardiovascular dysfunction as metabolic abnormalities [6, 7]. Additionally, PCOS is linked to psychiatric disorders such as anxiety, depression, eating disorders, and diminished quality of life [8, 9]. The etiology of PCOS is not well known yet, but it seems to be a multifactorial condition that can originate from genetic factors, epigenetic agents, prenatal androgen exposure, and environmental factors. Also, incorrect eating habits, stress, low levels of physical activity, and smoking are associated with the development of this syndrome [10–12]. Thus, it has been suggested that lifestyle modification is considered as first-line treatment in the management of PCOS [13]. These strategies majority focus on dietary changes, physical activity, and weight loss [14, 15]. Previous investigations have assessed the association between PCOS and nutrients, foods, and food groups. A review study indicated that a high-calorie diet rich in foods with a high glycemic index, saturated fatty acids, and insufficient fiber might affect metabolic outcomes in PCOS women [16]. Results of a case–control study showed that the women with PCOS had lower consumption of extra-virgin olive oil, legumes, fish/seafood, and nuts in comparison to the control group. Furthermore, despite similar energy intake levels between the two groups, the PCOS women had a lower intake of complex carbohydrates, fiber, monounsaturated fatty acids (MUFA), and n- 3 polyunsaturated fatty acid (PUFA) along with a higher intake of simple carbohydrates, total fat, saturated fatty acid (SFA), PUFA and n- 6 PUFA than the women without PCOS [17]. In contrast to the previous reports, the study of Moran et al. found that the dietary quality of women with PCOS was marginally better than that of women without PCOS, in the way that their intake of fiber and micronutrients was higher, and intake of SFA was lower. However, the study also noted that women with PCOS had higher resting time and energy consumption compared to the control group [18]. Although no study has directly examined the association between meat consumption and PCOS, limited studies have been conducted on the association of meat consumption with risk factors associated with PCOS. For instance, Panagiotakos et al. reported a positive association between red meat intake and hyperglycemia and hyperinsulinemia in a cross-sectional study [19]. Additionally, findings from a longitudinal study with an 8.8-year follow-up among women suggested that higher consumption of total red meat, mainly processed meat, may increase the risk of developing type 2 diabetes [20].

The present study aims to address a significant gap in the existing research on PCOS by exploring the association between different types of meat consumption and PCOS in Iranian women. While previous studies have examined various dietary factors in relation to PCOS, there is a notable lack of research specifically focusing on the impact of different meat types on this condition. Additionally, this research may contribute to a better understanding of the complex interplay between dietary habits-particularly meat intake-and hormonal imbalances associated with PCOS. The focus on Iranian women also adds a cultural and geographical dimension to the study, potentially revealing population-specific dietary patterns and their effects on PCOS prevalence in this demographic.

Materials and methods

Study design and participants

Women who were referred to the Yazd Diabetes Clinic and Khatam Clinic between January 2018 and March 2019 participated in the study. The endocrinology specialist also presented a few volunteers from other clinics around the city who satisfied the inclusion requirements to get more conclusive and acceptable findings. 117 women with PCOS were diagnosed by an endocrinologist based on Rotterdam criteria standard [21], including the presence of at least two of the three diagnostic tests: menstrual abnormalities, biochemical or clinical symptoms of hyperandrogenism, abnormal ovarian ultrasound findings such as less than 12 follicles per ovary with a diameter of 2 to 9 mm, or an increased ovarian volume of more than 10 cm^3 are all examples of abnormal ovarian ultrasound findings [4, 22]. The following were the case group's inclusion criteria: women of reproductive age (17–46 years old) who were newly diagnosed with PCOS; women without a history of conditions like hyperprolactinemia, Cushing syndrome, hypothyroidism, congenital adrenal hyperplasia, or food allergies; women without a history of using drugs like contraceptive pills, hormonal drugs, or other medications that could change the density of androgens; women without type 1 diabetes; women who did not drink alcohol or were not smokers; women who were not on a specific diet during the previous year. In addition, women who did not take supplements (such as vitamin D and E) during the past 3 months were included. The control group consisted of 119 women who had no symptoms of PCOS and were patients sent to other departments of the same clinic or hospital, such as orthopedics, dentistry, or optometry. Using a frequency matching technique, the BMI and age of two groups were matched. Therefore, first, we categorized our PCOS cases into age and BMI groups. Individuals were subdivided into age groups of 13–24, 25–34, 35–39 and >40 years and BMI groups of <25, 25–30, and >30 kg/m^2.

Finally, for the case group: 3 women declined to participate, 4 cases were not newly diagnosed, and 2 had food allergies. for the control group: 2 women were not willing to participate and 9 had food allergies; as a result, 216 women including 108 cases (response rate (92%)) and 108 controls (response rate (90%)) completed study based on matching for age and BMI. Although the number of subjects in the control group was slightly higher than the case group, but after matching for age and BMI with the case group, 108 participants remained in each group. Other inclusion criteria were almost equal for the case and control groups. The participants'recruitment procedures are represented in Fig. 1. After being briefed about the study's methodology, each participant signed a written informed consent form. The Human Research Ethics Committees of Shahid Sadoughi University of Yazd Medical Sciences approved the study protocol (IR.SSU.SPH.REC.1402.129).

Sample size calculation

Because of the limited number of similar articles, the minimum required sample size, considering alpha of 0.05 and a power of 90%, assuming that there is a 20% difference in adherence to the dietary patterns in the two groups (P1 = 40%, P2 = 60%), and a 10% probability of sample loss, was calculated to be 108 women in each group.

P1 = the ratio of people who followed the dietary pattern among the women without PCOS.

P2 = the ratio of people who followed the dietary pattern among the women with PCOS.

$$n = \frac{\left(Z_{1-\alpha/2}\sqrt{2PQ} + Z_{1-\beta}\sqrt{P_1Q_1 + P_2Q_2}\right)^2}{(P_1 - Q_1)^2}$$

where $P = \frac{P_1+P_2}{2}, Q = 1 - P, Q_1 = 1 - P_1, Q_2 = 1 - P_2$

Anthropometric measurements

All anthropometric characteristics were assessed while fasting using standard techniques by a qualified investigator. The participants were standing straight and barefoot when their height was measured with a non-stretched wall-mounted tape measure (the measurement's precision is 0.1 cm or less). Body weight was measured using Omron digital scales to the nearest 0.1 kg. Afterward, waist circumference (WC) was measured using a non-elastic tape measure (the degree of precision was closest to 0.5 cm) positioned roughly between the lower rib and iliac crest in a standing posture. BMI was then determined by dividing weight (kg) by height (m2).

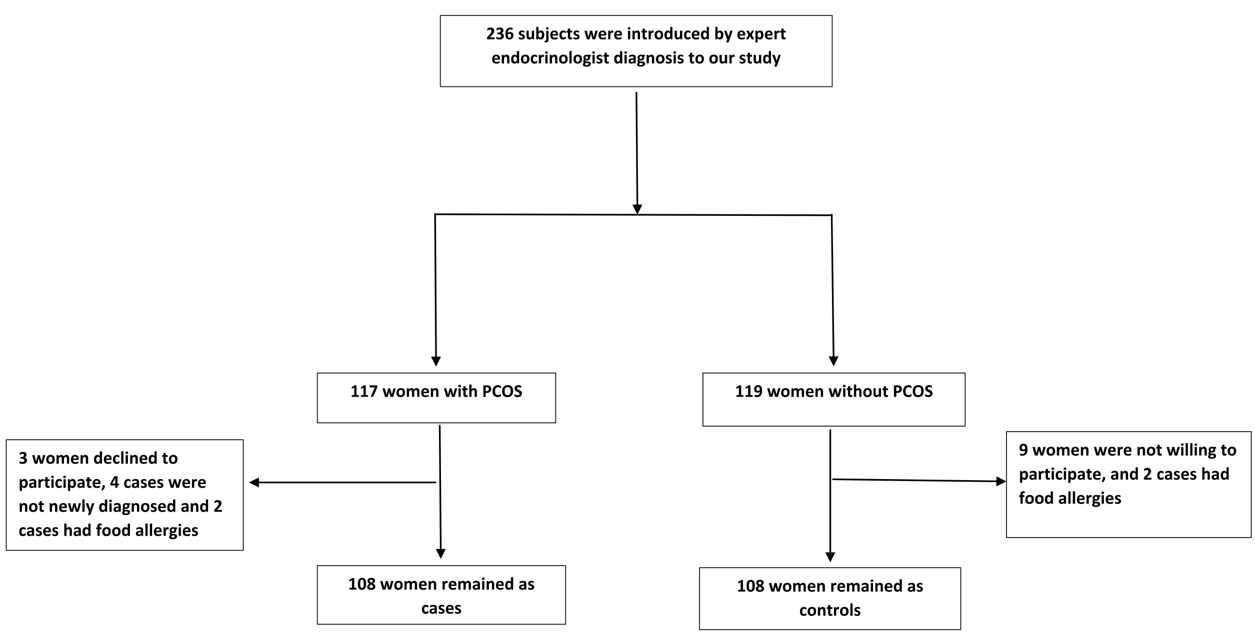

Fig. 1 The participants'recruitment procedures are represented in Fig. 1

Physical activity assessment

Data on physical activity were evaluated using the International Physical Activity Questionnaire-Short Form (IPAQ-SH) [23]. The overall score of the activity (MET-min/wk) was calculated by summing the scores for each kind of activity.

Dietary intake assessment

Each participant's typical dietary consumption over the previous year was assessed using a 178-item semi-quantitative food frequency questionnaire (FFQ) with 551 questions, which was previously validated in the study by Zimmerot et al. [24]. The frequency intake of each food item was reported as daily, weekly, monthly, or yearly. The typical portion sizes and frequency of food consumption and beverage items were questioned to improve the precision and accuracy of the estimates. The frequency was then changed to daily consumption, and the home measurements were used to convert the portion sizes to grams. To calculate the total energy and nutrient intake, the real food intake (g/d) was uploaded to Nutritionist IV [25].

Assessment of other covariates

A validated self-administered checklist was used to collect additional necessary variables, including age, marital status (single/married, widowed, divorced), pregnancy history, chronic disease history (hypertension, diabetes, cardiovascular diseases), PCOS drug use, and educational level (Illegal, Lower than diploma, Diploma & Associate's degree, Bachelor, Master, and above).

Statistical analysis

Continuous and categorical variables were expressed as mean ± standard deviation (SD) and frequencies (percentages), respectively. The normality distribution of continuous variables was checked by the Kolmogorov–Smirnov test. The chi-square test and independent t-test were performed to compare qualitative and quantitative variables, respectively. Also, one-way ANOVA was performed to compare quantitative variables in tertiles of meat consumption. Moreover, multivariate logistic regression was used in different models to discover the association between meats and PCOS. Model 1 was adjusted for total energy intake. Further adjustments were for marital status, physical activity, education, pregnancy history, and chronic disease history. Data analysis was conducted using SPSS software version 24 (IBM, Armonk, NY, USA) and a P-value ≤ 0.05 was considered statistically significant.

Results

Characteristics, energy intake, and physical activity of the women in both groups was shown in Table 1. No significant differences were observed in age, weight, BMI, physical activity, marital status, pregnancy history and chronic disease history for PCOS and education between the case and the control group. The WC in the case group was marginally higher than the control group ($P = 0.051$). Also, the mean intake of energy, red meats, organ meats, processed meats and poultry was significantly higher in the case group than in the control group ($P < 0.05$).

The characteristics of the women across tertiles of meat intake are indicated in Table 2. Married participants had more red and processed meat intake than single people ($P = 0.016$). Also, WC and BMI were higher in participants with a higher intake of processed meat than in people with a lower intake ($P < 0.05$). Also, there was a significant difference in fish consumption among women of different ages ($P = 0.013$).

Dietary intake of the study participants based on tertiles of meat intake are illustrated in the Table 3. For the participants with the highest intake of red meat, the mean intake of energy, protein, fat, cholesterol, saturated fatty acids, monounsaturated fatty acids and vitamin B12 were significantly higher than those with the lowest red meat, while their daily carbohydrate intake was significantly lower. Participants with a higher intake of organ meats significantly have higher energy, polyunsaturated fatty acid, vitamin B6 and B12 intake. Also, participants in the third tertile intake of processed meat had a higher intake of energy, fat, saturated and monounsaturated fatty acids than those in the first tertile, while they had less calcium, vitamin A and B6 intake. In addition, the increase in poultry intake was associated with increased protein, iron and folate intake. With the increase in fish intake from the first to the third tertile, the intake of energy, carbohydrate, and vitamin B12 increased, while the intake of fat and saturated and monounsaturated fatty acids decreased significantly.

Crude and multivariable-adjusted Odds Ratio (OR) and 95% Confidence Interval (CI) of the associations between PCOS and different types of meats is shown in Table 4. The individuals in the third tertile of red meat intake, had higher odds for PCOS in the crude model (OR = 4.29; 95% CI, 2.13–8.64); P-value and trend = 0.001) compared with those in the first tertile. These results remained significant after adjustments for energy intake, marital status, physical activity, education, pregnancy history and chronic disease history (OR = 3.87; 95% CI, 1.78–8.40; P-value and trend = 0.001). Higher consumption of red meat increased the risk of PCOS by 3.87 times.

Furthermore, the individuals in the third tertile of processed meats, had higher odds for PCOS in the crude

Table 1 General characteristics, energy intake, and physical activity of women with and without PCOS

Variables	Case (n = 108)	Control (n = 108)	P value*
Age (y)	28.95 ± 7.16	30.45 ± 7.17	0.126
Weight (kg)	70.07 ± 12.95	70.11 ± 13.01	0.980
BMI (kg/m2)	27.10 ± 4.88	26.63 ± 4.87	0.482
WC (cm)	82.74 ± 10.77	79.74 ± 11.62	0.051
PA (MET-min/wk)	1426 ± 760.71	1493.55 ± 793.42	0.525
Marital status			
Single	39(36.1)	41(38)	0.778
Married	69(63.9)	67(62)	
Pregnancy history			
No	45(41.7)	49(45.4)	0.583
YES	63(58.3)	59(58.3)	
Chronic disease history			
No	61(56.5)	62(57.4)	0.891
YES	47(43.5)	46(42.6)	
Education			
Ilegal	1 (0.9)	0	0.275
Lower than diploma	13 (12)	16(14.8)	
Diploma & Associate's degree	37(34.3)	26(24.1)	
Bachelor	47(43.5)	59(54.6)	
Master and above	10(9.3)	7(6.5)	
Energy intake (kcal)	2323.84 ± 803.28	1882.85 ± 566.74	< 0.001
Red meats (gr)	56.64 ± 41.19	37.14 ± 35.28	< 0.001
Organ meats (gr)	5.85 ± 24.08	1.11 ± 2.45	0.043
Processed meats (gr)	8.82 ± 15.08	3.92 ± 7.27	0.003
Poultry (gr)	43.99 ± 54.17	27.20 ± 28.08	0.005
Fish (gr)	9.95 ± 10.49	9.95 ± 9.60	0.999

BMI body mass index, *MET* metabolic equivalent, *PA* physical activity, *PCOS* polycystic ovary syndrome, *WC* waist circumference

For quantitative variables mean ± SD; and for qualitative variables frequency (%) were used

* Independent t test for quantitative variables and Chi-square test for categorical variables conducted

model (OR = 2.92; 95% CI, 1.50–5.68); P-value and trend = 0.002) compared with those in the first tertile. These results remained significant after adjustments for energy intake, marital status, physical activity, education, pregnancy history and chronic disease history (OR = 2.15; 95% CI, 1.05–4.39; P-value and trend = 0.035). Higher consumption of processed meats increased the risk of PCOS by 2.15 times.

Discussion

To the best of our knowledge, this is the first case–control study characterizing the association between meat consumption and the risk of PCOS in women. The findings of the present study showed that red meat and processed meat consumption were positively associated with the risk of PCOS, however, no association was found between the consumption of poultry, fish and organ meat with the risk of PCOS. Previous studies examined the relationship between dietary general characteristics with the risk of PCOS. However, little is known about the association between food groups and their special characteristics with the risk of PCOS [26–28]. In line to our study, Badri-Fariman et al. [28] in a case–control study found that the PCOS patients had a significantly higher intake of processed meats, red and organ meats and saturated fatty acids compared to healthy subjects [28]. In contrast to our study, Hosseini et al. [26], indicated that more intakes of seafoods, was associated with lower risk of PCOS [26]. Insulin resistance related to increased insulin levels and obesity are the main characteristics of PCOS in women [29]. The association between high consumption of protein with glycemic responses is controversial [30, 31]. In addition, due to their high fat content, meats have been related to the risk of obesity and development of inflammation [32].

Some review studies have been conducted to investigate dietary intake in PCOS patients. In general, these studies showed that low glycemic index diet and low

Table 2 Characteristics of the study participants across tertiles of meat intake [a, b]

Variables	Red meats				Organ meats				Processed meats				Poultry				Fish			
	T1 (≤ 24.06)	T2 (24.60–54.60)	T3 (≥ 54.96)	P	T1 (≤ 0.08)	T2 (0.17–1.06)	T3 (≥ 1.08)	P	T1 (< 0.55)	T2 (0.55–4.36)	T3 (≥ 4.80)	P	T1 (≤ 11.87)	T2 (12.50–34.74)	T3 (≥ 35.61)	P	T1 (≤ 4.36)	T2 (4.65–10.05)	T3 (≥ 10.57)	P
Age(year)	28.34 ± 6.80	30.79 ± 7.11	29.97 ± 7.52	0.116	30.20 ± 7.10	29 ± 7.50	29.76 ± 7.06	0.063	30.22 ± 7.61	28.04 ± 6.44	30.64 ± 7.17	0.079	29.13 ± 7.0	31.50 ± 7.14	29.01 ± 7.23	0.094	29.86 ± 6.61	27.84 ± 7.56	31.37 ± 7.05	0.013
Weight(Kg)	70.25 ± 12.19	71.44 ± 13.43	68.8 ± 13.05	0.412	69.65 ± 13.46	69.83 ± 11.50	70.83 ± 13.56	0.839	67.38 ± 11.21	69.08 ± 11.23	74.36 ± 15.19	0.030	67.48 ± 12.52	69.98 ± 11.40	72.84 ± 13.83	0.031	70.47 ± 12.83	69.66 ± 13.94	70.13 ± 12.02	0.931
BMI (Kg/m2)	27.17 ± 4.74	27.26 ± 4.97	26.17 ± 4.87	0.331	26.46 ± 7.74	27.01 ± 4.67	27.19 ± 5.21	0.624	25.77 ± 4.36	26.52 ± 4.19	28.52 ± 5.61	0.002	26.06 ± 4.55	26.86 ± 4.23	27.69 ± 5.48	0.107	26.79 ± 4.70	26.51 ± 4.90	27.28 ± 5.03	0.632
WC (cm)	81.36 ± 11.05	81.84 ± 11.61	80.52 ± 11.29	0.778	80.55 ± 11.23	80.46 ± 10.92	82.73 ± 11.65	0.399	79.85 ± 10.36	80.10 ± 11.21	84.02 ± 12.05	0.047	79.08 ± 10.61	81.70 ± 9.66	83.13 ± 12.68	0.071	81.19 ± 10.63	79.83 ± 11.68	82.68 ± 11.49	0.323
PA	1385.72 ± 713.37	1395.04 ± 771.97	1598.92 ± 830.64	0.177	1500.27 ± 832.42	1381.4 ± 724.5	1484.55 ± 760.08	0.626	1526.72 ± 853.99	1416.57 ± 761.40	1419.74 ± 691.23	0.609	1518.53 ± 825.16	1490.8 ± 818.6	1377.82 ± 691.78	0.490	1481.22 ± 771.75	1475.92 ± 823.6	1475.92 ± 741.11	0.880
Marital status																				
Single	36(50)	24(33.3)	20(27.8)	0.016	36(44.4)	22(34.4)	22(31)	0.200	36(50)	24(33.3)	20(27.8)	0.016	30(37)	22(39.3)	28(35.4)	0.901	24(32.9)	31(43.7)	25(34.7)	.0.360
Married	36(50)	48(66.7)	52(72.2)		45(55.6)	42(6.6)	49(69)		36(50)	48(66.7)	52(72.2)		51(63)	34(60.7)	51(64.60		49(67.1)	40(56.3)	47(65.3)	
Pregnancy History																				
No	24(33.3)	35(48.6)	35(48.6)	0.102	34(42)	28(43.8)	32(45.1)	0.928	24(33.3)	35(48.6)	35(48.6)	0.102	37(45.7)	23(41.1)	34(43)	0.862	36(49.3)	28(39.4)	30(41.7)	0.454
Yes	48(66.7)	37(51.4)	37(51.4)		47(58)	36(56.3)	39(54.9)		48(66.7)	37(51.4)	37(51.4)		44(54.6)	33(58.9)	45(57)		37(50.7)	43(60.6)	42(58.3)	
Chronic disease history																				
No	47(65.3)	37(51.4)	39(54.2)	0.205	43(53.1)	33(51.6)	47(66.2)	0.155	47(65.3)	37(51.4)	39(54.2)	0.205	44(54.3)	36(47.3)	43(54.3)	0.436	35(47.9)	41(57.7)	47(65.3)	0.107
Yes	25(34.7)	35(48.6)	33(45.8)		38(46.9)	31(48.4)	24(33.8)		25(34.7)	35(48.6)	33(45.8)		37(45.7)	20(35.7)	36(45.6)		38(52.1)	30(42.3)	25(34.7)	
Education																				
Ilegal	1(1.4)	0	0	0.090	1(1.2)	0	0	0.479	1(1.4)	0	0	0.090	1(1.2)	0	0	0.473	1(1.4)	0	0	0.723
Lower than diploma	12(16.7)	10(13.9)	7(9.7)		11(13.6)	7(10.9)	11(15.5)		12(16.7)	10(13.9)	7(36.1)		14(17.3)	4(7.1)	11(13.9)		9(12.3)	10(14.1)	10(13.9)	
Diploma	25(30.6)	12(20.5)	26(36.1)		22(27.2)	16(25)	25(32.2)		25(34.7)	12(16.7)	26(36.1)		26(32.1)	15(26.8)	22(27.8)		25(34.2)	21(29.6)	17(23.6)	
Bachelor	29(40.3)	45(62.5)	32(44.4)		40(47.4)	38(59.4)	28(39.4)		29(40.3)	45(62.5)	32(44.4)		35(43.2)	30(53.6)	41(51.9)		33(45.2)	36(50.7)	37(51.4)	
Master and above	5(6.9)	5(6.9)	7(9.7)		7(8.6)	3(4.7)	7(9.9)		5(6.9)	5(6.9)	7(9.7)		5(6.2)	7(12.5)	5(6.3)		5(6.8)	4(5.6)	8(11.1)	

BMI body mass index, *MET* metabolic equivalent, *PA* physical activity, *PCOS* polycystic ovary syndrome, *WC* waist circumference

[a] For quantitative variables mean ± SD; and for qualitative variables frequency (%) were used

[b] One-way ANOVA for quantitative variables and Chi-square test for categorical variables conducted

Table 3 Dietary intake of the study participants based on tertiles of meat intake [a, b]

	Red meats			Organ meats			Processed meats			Poultry			Fish		
	T1	T3	P[1]	T1	T3	P[1]	T1	T3	P[1]	T1	T3	P[1]	T1	T3	P[1]
Energy(kcal)	1943.28 ± 797.50	2341.36 ± 671.93	0.022	1957.29 ± 628.66	2358.96 ± 779.19	0.001	1903 ± 675.43	2410.27 ± 801.83	< 0.001	1954.97 ± 656.78	2357.82 ± 805.56	<0.001	1923.89 ± 611.51	2313.21 ± 711.10	0.005
Carbohydrate(%)	62.51 ± 0.06	55.60 ± 0.07	<0.001	59 ± 0.07	58.33 ± 0.06	0.448	61.73 ± 0.05	56.93 ± 0.07	<0.001	59.97 ± 0.07	57.80 ± 0.07	0.148	57.30 ± 0.07	59.28 ± 0.07	0.022
Protein(%)	15.38 ± 0.03	16.65 ± 0.03	0.037	16.15 ± 0.02	15.89 ± 0.02	0.757	16.08 ± 0.02	15.55 ± 0.03	0.398	14.52 ± 0.02	17.55 ± 0.03	<0.001	15.67 ± 0.03	15.97 ± 0.02	0.497
Fat(%)	25.51 ± 0.05	30.99 ± 0.05	<0.001	27.93 ± 0.06	29.15 ± 0.06	0.241	25.58 ± 0.05	30.40 ± 0.05	<0.001	28.22 ± 0.06	28.54 ± 0.05	0.687	29.73 ± 0.05	28.06 ± 0.06	0.013
Cholesterol(mg)	99.86 ± 44.23	130.42 ± 40.28	0.001	118.18 ± 47.58	118.86 ± 42.83	0.761	116.68 ± 55.65	112.49 ± 44.38	0.568	116.34 ± 60.68	123.13 ± 42.87	0.260	118.87 ± 56.08	112.58 ± 45.28	0.672
Saturated fatty acid (gr)	8.32 ± 2.62	11.21 ± 2.25	<0.001	9.82 ± 3.10	9.73 ± 2.58	0.432	8.76 ± 2.70	9.99 ± 2.65	0.001	10 ± 2.94	9.51 ± 2.52	0.227	10.51 ± 2.80	9.21 ± 2.17	0.003
Monounsaturated fatty acid(gr)	8.12 ± 1.90	10.79 ± 2.36	<0.001	9.34 ± 2.72	9.72 ± 2.38	0.441	8.12 ± 2.19	10.50 ± 2.21	<0.001	9.29 ± 2.83	9.64 ± 2.31	0.603	10.01 ± 2.37	9.33 ± 2.94	0.029
Polyunsaturated fatty acid(gr)	11.30 ± 6.69	10.99 ± 7.90	0.949	10.78 ± 6.51	9.27 ± 4.59	0.001	11.55 ± 7.08	9.95 ± 5.46	0.196	12.31 ± 9.24	10.09 ± 4.89	0.149	11.42 ± 7.50	12.03 ± 8.11	0.291
Calcium(mg/1000 kcal)	405.43 ± 126.01	364.15 ± 91.58	0.079	398.57 ± 127.15	363.49 ± 89.88	0.156	411.26 ± 112.69	352.50 ± 113.15	0.005	420.75 ± 131.75	352.80 ± 91.71	<0.001	387.49 ± 117.21	379.58 ± 106.16	0.898
Iron(mg/1000 kcal)	22.05 ± 23.59	22.29 ± 34.95	0.298	24.07 ± 32.41	17.24 ± 23.99	0.219	24.30 ± 21.96	19.73 ± 33.03	0.117	16.92 ± 15.55	17.56 ± 21.40	0.011	18.05 ± 21.96	18.88 ± 23.07	0.315
VitaminA (mg/1000 kcal)	8.73 ± 7.12	10.83 ± 8.46	0.204	10.15 ± 9.05	9.74 ± 7.92	0. 385	11.48 ± 9.30	7.87 ± 6.65	0.011	9.80 ± 8.09	10.35 ± 8.52	0.168	10.26 ± 8.17	9.16 ± 7.29	0.591
Vitamin C (mg/1000 kcal)	86.01 ± 36.64	102.16 ± 52.66	0.078	92.83 ± 41.82	98.30 ± 42.18	0.341	98.71 ± 45.98	83.27 ± 38.41	0.085	91.14 ± 50.94	99.15 ± 42.94	0.249	86.93 ± 46.18	100.45 ± 42	0.174
Folate(mcg/1000 kcal)	145.07 ± 40.58	135.48 ± 36.25	0.289	143.36 ± 32.43	145.94 ± 43.34	0.052	146.09 ± 34.09	138.20 ± 39.40	0.225	133.88 ± 35.07	148.26 ± 37.79	0.046	134.38 ± 39.03	147.83 ± 35.78	0.087
Vitamin B6 (mg/1000 kcal)	0.83 ± 0.31	0.84 ± 0.26	0.692	0.85 ± 0.21	0.89 ± 0.31	0.045	0.89 ± 0.31	0.78 ± 0.19	0.041	0.84 ± 0.35	0.86 ± 0.18	0.556	0.82 ± 0.25	0.88 ± 0.32	0.328
Vitamin B12 (mcg/1000 kcal)	1.50 ± 0.61	2.14 ± 0.66	<0.001	1.73 ± 0.64	1.99 ± 0.85	0.046	1.77 ± 0.61	1.85 ± 0.61	0.760	1.82 ± 0.67	1.81 ± 082	0.992	1.73 ± 0.70	2.01 ± 0.79	0.023

[a] Data reported on mean ± SD

[b] One-way ANOVA, were used

[*] Statistically significant difference (*P*-value < 0.05)

Table 4 Odds ratio and 95% confidence interval for the occurrence of PCOS across tertiles of different types of meat

Variable	Tertiles of red meat intake			*P* value[‡]	P trend[‡]
PCOS	**T1**	**T2**	**T3**		
Crude	1.00	1.33 (0.68_2.61)	4.29 (2.13_8.64)	<0.001	< 0.001
Model I*	1.00	1.27 (0.63_2.56)	3.40 (1.64_7.07)	0.001	0.001
Model II**	1.00	1.37 (0.66_2.84)	3.87 (1.78_8.40)	0.001	0.001
Tertiles of organ meat intake					
PCOS	T1	T2	T3		
Crude	1.00	0.64[†] (0.33_1.26)	1.86 (0.97_3.57)	0.061	0.075
Model I*	1.00	0.60 (0.30_1.21)	1.39 (0.70_2.76)	0.344	0.415
Model II**	1.00	0.57 (0.28_1.17)	1.36 (0.67_2.75)	0.390	0.480
Tertiles of processed meats intake					
PCOS	T1	T2	T3		
Crude	1.00	1.54(0.80_2.98)	2.92(1.50_5.68)	0.002	0.002
Model I*	1.00	1.42(0.72_2.80)	2.08(1.02_4.22)	0.042	0.041
Model II**	1.00	1.42(0.71_2.81)	2.15 (1.05_4.39)	0.035	0.035
Tertiles of poultry intake					
PCOS	T1	T2	T3		
Crude	1.00	0.82 (0.41_1.65)	1.84 (0.98_3.45)	0.057	0.059
Model I*	1.00	0.81 (0.40_1.67)	1.37 (0.70_2.67)	0.350	0.370
Model II**	1.00	0.81 (0.39_1.68)	1.35 (0.69_2.66)	0.374	0.388
Tertiles of fish intake					
PCOS	T1	T2	T3		
Crude	1.00	0.71 (0.36_1.37)	1.28 (0.66_2.47)	0.450	0.455
Model I*	1.00	0.59 (0.29_1.20)	0.91 (0.45_1.83)	0.803	0.953
Model II**	1.00	0.58 (0.29_1.19)	0.89 (0.44_1.82)	0.764	0.754

[†] These values are odds ratios (95% CIs)

[*] Third tertile compared to first tertile

[‡] Obtained from logistic regression

[*] Adjusted for total energy intake

[**] Additionally adjusted for marital status, physical activity, education, pregnancy history, chronic disease history

amount of fat, especially saturated fat and trans fatty acids lead to weight loss, improve insulin resistance, metabolic and reproductive parameters [33–35].

Also, we observed that along with the increase in meat consumption, the mean intake of total fat and saturated fat went up. In line to our study, Navarro-Lafuente et al. [36] observed that higher intake of saturated fatty acids has been associated with some PCOS phenotypes [36]. In a study by Amirjaniet al [37] had been demonstrated that PCOS women a greater intake of total fat and saturated fatty acids [37]. By reviewing the studies, we found that inconsistency in results of different studies could be related to the, differences in study design, study population, and the effect of genetic and racial factors [38].

Some mechanisms have been suggested to describe the association between meat consumption and higher risk of PCOS. Based on a possible mechanism, animal proteins intake compared to plant proteins, can contribute to the increased risk of PCOS by increasing the level of insulin-like growth factor (IGF-I) [39]. Inflammation is involved in the pathogenesis of PCOS. It has been reported that, inflammatory agents, like CRP and TNF, reduce insulin sensitivity and, therefore increase insulin resistance. Also, dietary components such as saturated fatty acid can affect inflammatory mediators, like IL- 1β and TNF-α and disturb insulin signaling pathway [40, 41]. Insulin resistance through accumulation visceral adipose tissue and disturbance of the synthesis or release of reproductive hormones, causes retention and increased levels of sex hormones can increase the risk of PCOS [42]. Inflammation-induced hyperglycemia increases glucose in mononuclear cells. followed by that, the increase in oxidation of this molecule and the production of reactive oxygen species cause disturbances in the synthesis of sex hormones and metabolic disorders involved in PCOS [43]. In addition, inflammatory cytokines cause more complex disorders of PCOS by increasing steroid synthesis and stimulating follicles associated with hyperandrogenism [44].

To the best of our knowledge, one of the strengths of this study was the utilization of a validated FFQ in the Iranian population. Moreover, this study is the first to investigate the association between meat consumption and PCOS among Iranian women, with the results adjusted for energy intake, marital status, pregnancy history, WC, drug history, and physical activity as confounding factors. However, the limitations of this study must be acknowledged. First, owing to the cross-sectional nature of this study, causal relationships cannot be inferred. Second, recall biases are possible owing to the retrospective and memory-dependent nature of FFQ. Third, measurement bias is inherent to any dietary assessment. fourthly the associations of metabolic and hormonal characteristics of study subjects with meat consumption has not been investigated. Furthermore, despite controlling for confounders, the effects of residual confounding factors could not be eliminated entirely. Consequently, a prospective study with a larger sample size and extended duration is necessary to assess this relationship comprehensively.

Conclusion

The present study showed that a higher consumption of red and processed meat is associated with a higher risk of PCOS, while there was no correlation between the consumption of poultry, fish, and organ meat and the incidence of PCOS. More longitudinal and prospective studies are needed to confirm the results in the future.

Abbreviations

FFQ	Quantitative food-frequency questionnaire
MET	Metabolic Equivalent
BMI	Body Mass Index
IPAQ	International Physical Activity Questionnaire
CI	Confidence Interval
OR	Odds Ratio
PCOS	PolyCystic Ovary Syndrome
WC	Waist Circumference
CRP	C-Reactive Protein
IL- 1β	Interleukin- 1β
TNF-α	Tumor Necrosis Factor Alpha

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Authors' contributions

M.D conceived and designed the study; generated, collected, assembled, analyzed, and interpreted the data; and drafted. M.H designed the study and the protocol and prepared data interpretation, made revision to the paper and prepared the final draft of the paper. M.GH, A.Gh, and V.A analyzed, and interpreted the data. All authors contributed to approve the final manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The survey was approved by the Ethics Committee of Shahid Sadoughi University of Medical Sciences, Yazd, Iran (IR.SSU.SPH.REC.1402.129). An Informed consent was taken from participants. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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