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Alternative healthy eating index may predict a reduced odd of endometriosis: results from a case-control study

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Abstract

Background Endometriosis, characterized as an inflammatory ailment, affects females during their reproductive years, leading to decreased quality of life. Despite the pivotal role of diet as a modifiable risk factor for various chronic conditions, its potential influence on endometriosis has remained inadequately explored. This research endeavor sought to scrutinize the association between dietary alternative healthy eating index, AHEI, and the likelihood of experiencing endometriosis among women in Iran.

Methods Conducted as a hospital-centered case-control investigation, the study enlisted individuals diagnosed with endometriosis alongside healthy counterparts, confirmed by a gynecologist, between February and September 2021 in Tehran, Iran. The pattern of diet was assessed utilizing a validated Food Frequency Questionnaire (FFQ) encompassing 168 food items. Logistic regression models were employed to explore the potential connection between AHEI and the probability of endometriosis.

Results The analysis encompassed 105 subjects with endometriosis and 208 individuals in good health. After adjustment for total calories intake (Kcal), occupation, smoking (yes/no), age at menarche (years), menstruation duration (days), regular menstruation (yes/no), physical activity (minutes per week) and familial history of endometriosis (yes/no), it was observed that those with the high adherence to the AHEI, had about 92% lower odds of endometriosis (Odds Ratio: 0.08, 95%Confidence Intervals: 0.03, 0.24; P for trend < 0.001).

Conclusion The investigation illustrated a protective effect of healthy eating index and its components on developing endometriosis.

Keywords Alternative healthy eating index, Endometriosis, Case-control

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Introduction

Endometriosis, a chronic inflammatory condition, is marked by the occurrence of tissue lesions outside the uterus, including areas such as the pelvis, peritoneum, ovaries, and rectovaginal septum [1, 2]. This benign disease, which is dependent on estrogen, impacts 10% of women in their reproductive years and is found in over 35% of women experiencing pelvic pain or infertility. However, its prevalence can fluctuate based on the diagnostic method and the population studied [3]. Given its chronic nature, associated comorbidities, and the diminished quality of life it imposes on patients, endometriosis poses a substantial medical, social, and economic burden [4]. Research to date has pinpointed several factors contributing to the onset of endometriosis, such as infertility, a family history of the disease, obstruction of menstrual outflow, a history of pelvic infection, and uterine abnormalities [5]. Consequently, endometriosis is categorized as a multifactorial genetic disease, with both genetic and environmental elements shaping its progression [6].

Several risk factors are proposed for the development and progression of endometriosis, including having a menstrual cycle shorter than 27 days, cervical stenosis, being aged between 25 and 29 years, and certain dietary factors [7]. Recently, the potential effectiveness of nutrition in controlling inflammation, regulating menstrual cycles, modulating estrogen activity levels, and managing prostaglandin metabolism in relation to the pathological and physiological processes of endometriosis has garnered attention [8, 9]. Evidence suggests that dietary habits can influence the disease's incidence, and specific dietary patterns seem to impact inflammatory factors such as interleukin (IL)-1β, IL-6, IL-8, macrophage migration inhibitory factor (MIF), tumor necrosis factor-α (TNF-α), and regulated on activation normal T expressed and secreted (RANTES), which are elevated in endometriosis [10, 11].

In recent years, several indices have been developed to evaluate diet quality, including the Alternative Healthy Eating Index (AHEI), which was designed to assess adherence to standard food pyramid guidelines [12]. Although a recent prospective study of dietary patterns and the incidence of endometriosis diagnosis has reported the protective effect of AHEI [13]; However, the methodology, the age range and the nationality of participants in this study is different from our study which could impact the observed results. So we decided to explore the connection between the AHEI, which represents an individual's diet quality, and the odds of developing endometriosis in Iranian women in reproductive age.

Methods

Ethical considerations

In accordance with the principles outlined in the Declaration of Helsinki [14], approval for the study was granted by the Medical Ethical Committee of the National Nutrition and Food Technology Research Institute at Shahid Beheshti University of Medical Sciences (IR SBMU. NNFTRI.REC.1399.062) in Iran. All individuals participating in the study provided written consent to ensure the confidentiality of the data.

Study design and population

Detailed information regarding the methods and materials employed was previously presented in our research [15]. Specifically, a case-control study based in a hospital setting was carried out, involving interviews with 115 newly diagnosed endometriosis patients and 230 control subjects in Tehran, Iran, between February and September 2021. Female participants eligible for inclusion, aged between 18 and 49 years, exhibited no underlying conditions that could potentially influence the outcomes of the study, as elucidated in the aforementioned investigation [15].

Exposure assessment

As delineated in the previously mentioned study [15], the evaluation of dietary intake relied on a validated 168-item Food Frequency Questionnaire (FFQ) [16] a validated food album [17] and visual aids depicting household measurements. The determination of daily energy and macronutrient intake was carried out utilizing either the USDA food composition Table [18] or the Iranian food composition Table [19]. Interviews and surveys were administered by an impartial interviewer, who remained uninformed about the outcomes of the participants, to decrease the likelihood of information bias.

Data collection pertaining to various anthropometric parameters was executed by the researchers [15], with levels of physical activity being gauged through the utilization of a dependable questionnaire developed by Aadahl et al. [20].

Outcome assessment

To address multicollinearity among individual dietary components such as sodium and trans fats, our analysis focused on dietary patterns rather than individual food items or nutrients. The AHEI is based on the original healthy eating index formulated by Kennedy et al. [21], with some modifications. Eleven elements, such as fruits, vegetables, whole grains, nuts, legumes, long-chain n-3 fatty acids (DHA and EPA), polyunsaturated fatty acids (PUFA), wine, sugar-sweetened beverages and fruit juice, red and processed meats, as well as trans-fat and sodium are included in this dietary pattern. In current study we

didn't have sufficient data on whole grains, wine and long-chain n-3 fatty acids (DHA and EPA) consumption, so we computed AHEI based on eight components. The omission of certain AHEI components (i.e., wine, long-chain omega-3 fatty acids, and whole grains) from our analysis was intentional and based on cultural, dietary, and methodological considerations specific to the Iranian population. In Iran, the consumption of alcohol, including wine, is prohibited for religious and cultural reasons, and reporting wine intake is a societal taboo. As a result, alcohol consumption is extremely rare and is not accurately captured in dietary assessments such as FFQs. Omitting this component was necessary to ensure cultural sensitivity and data accuracy [22]. Iranian dietary patterns are low in omega-3 fatty acid-enriched fish (e.g., salmon, mackerel) that are common sources of long-chain omega-3 fatty acids. The available fish types in Iran (such as Caspian kutum and white fish) contain significantly lower levels of long-chain omega-3 fatty acids, and data on omega-3 intake from our FFQ are not reliable or valid for this component [23]. Finally, Whole grain consumption is uncommon in Iran. Traditional Iranian breads, such as lavash, sangak, and barbari, are primarily made from refined flour. Since whole grain intake is not representative of the Iranian diet and is not accurately measurable through the FFQ, it was excluded from the analysis [24]. Individuals positioned in the top decile for vegetables, fruits, nuts, legumes, and PUFA received a maximum score of 10, whereas those with the lowest intake were assigned a score of 1. Participants falling into other deciles were allocated scores proportionate to their consumption levels. Totally converse calculation method was performed for the intakes of sugar-sweetened beverages and fruit juice, red and processed meats, trans fatty acids, and sodium. These ten components were summed to determine the overall AHEI score for each participant. The range was between 8 and 80.

Statistical analysis

The statistical analysis was performed utilizing SPSS (Statistical Package for the Social Sciences program; version 27; Chicago, IL, USA). Two-tailed analyses were conducted, with P-values below 0.05 being deemed statistically significant. Prior to further analyses, continuous variables were assessed for normal distribution via measures such as skewness, histograms, Q-Q plots, and the Kolmogorov-Smirnov test. Descriptive statistics such as mean (SD) or median (interquartile range, IQR) were employed for normally and non-normally distributed quantitative traits, respectively. Categorical demographic features were presented as frequencies and percentages. The Independent Samples T-test or Mann-Whitney test was applied for the comparison of normally and non-normally distributed quantitative variables, respectively. A comparison between qualitative data was achieved using the Chi-square test. Crude and adjusted odds ratios (OR) for endometriosis were computed utilizing a 95% confidence interval (CI) through logistic regression to explore the association between AHEI and endometriosis. The total AHEI in the regression model was calculated using the energy adjusted components through residual method. We conducted a post-hoc analysis to assess multicollinearity among the components of the AHEI using the variance inflation factor (VIF). All VIF values were below the standard cutoff of 10, indicating that multicollinearity was not a concern in our data. Adjustment for occupation, smoking (yes/no), age at menarche, menstruation duration, regular menstruation, familial history of endometriosis (yes/no) and physical activity (minutes/week) was undertaken to derive adjusted ORs.

According to the study by Mirmiran et al. 55% of the adult women population in Tehran, intake higher than 1% of trans fatty acids. The OR for endometriosis was postulated 2 by researchers. Considering the number of people in the case group to the control group equal to 1 to 2, a total of 115 endometriosis-affected women (cases) and 210 healthy women (controls) were calculated to attain 80% statistical power for such effect size at a 5% level of significance and 10% loss to follow-up [25, 26].

Results

The general characteristics of the participants were delineated in a previous investigation [15]. Amongst a total of 317 participants (107 diagnosed with endometriosis), 4 individuals were eliminated from the analysis due to energy consumptions falling below 600 or exceeding 4200 kcal. Subsequently, the research encompassed 105 participants with endometriosis and 208 individuals without the condition.

General characteristics of participants with endometriosis and healthy controls, separated according to AHEI adherence are shown in Table 1. No significant differences were observed between those with low and high adherence to the AHEI in both endometriosis and healthy groups regarding age (years), and age at menarche (years). In healthy controls, patients with high adherence to the AHEI had higher weight, BMI and waist circumference (WC) (P-value < 0.05) that could be due to higher amounts of calories intake (Kcal, P-value = 0.003). In patients with endometriosis, those with low adherence to the AHEI had higher weight (kg) and BMI (kg/m^2, P-value < 0.005). No significant association was observed between patients with low and high adherence to the AHEI in both endometriosis and healthy groups considering familial history of endometriosis, education, cigarette smoking, and employment (Table 1).

Data on participants' education levels (e.g., Primary/secondary school, Diploma, Bachelor's degree, Master's/

Table 1 General characteristics of participants with endometriosis and healthy controls, separated according to alternative healthy eating index adherence

	Healthy controls ***N*** **= 208**					**Participants with endometriosis** ***N*** **= 105**				
	Low adherence to the Alternative Healthy Eating Index *N* = 111		High adherence to the Alternative Healthy Eating Index *N* = 97		P-value*	Low adherence to the Alternative Healthy Eating Index *N* = 100		High adherence to the Alternative Healthy Eating Index *N* = 5		P-value*
	Median	Q1-Q3	Median	Q1-Q3		Median	Q1-Q3	Median	Q1-Q3	
Age, year	30.00	27.00–34.00	31.00	28.00–36.00	0.284	36.00	30.00-39.75	35.00	34.50–42.00	0.493
Age at menarche, year	13.00	12.00–14.00	13.00	12.00–14.00	0.269	13.00	11.00–15.00	13.00	12.00–14.00	0.826
Physical activity, Minutes/week	10.00	0.00–60.00	20.00	1.00-120.00	**0.038**	30.00	1.25–73.75	0.00	0.00-225.00	0.312
Weight, kg	61.00	53.00–68.00	64.00	57.50–72.00	**0.024**	71.00	64.25–82.75	57.00	49.50–68.00	**0.014**
Body Mass Index, kg/m^2	23.71	21.08–25.78	24.30	22.48–28.01	**0.023**	27.92	23.90-30.08	22.27	20.82–25.53	**0.019**
Waist circumference, cm	83.00	74.00–90.00	85.00	76.50–95.00	**0.036**	85.00	78.00–92.00	80.00	74.00–82.00	0.091
Calories intake, Kcal	1842.23	1425.29-2421.40	2138.94	1801.41-2704.92	**0.003**	2171.14	1775.30-3090.67	1753.30	1431.14-2112.44	0.107
	Number	Percentage	Number	Percentage	P-value**	Number	Percentage	Number	Percentage	P-value**
Married	60	54.1	73	75.3	**0.002**	57	57	5	100	0.077
Having familial history of Endometriosis	4	3.6	2	2.1	0.687	51	51	1	20	0.363
Education					0.119					0.174
Primary/secondary school	10	9	10	10.3		11	11	2	40	
Diploma	24	21.6	25	25.8		23	23	0	0	
Bachelor's degree	50	45	51	52.6		49	49	2	40	
Master's/Doctoral degree	27	24.3	11	11.3		17	17	1	20	
Cigarette smoking										
Yes	19	17.1	15	15.5	0.630	24	24	0	0	0.203
Past smokers	3	2.7	5	5.2		25	25	0	0	
Never smokers	89	80.2	77	79.4		51	51	5	100	
Employed	71	64	62	63.9	0.918	43	43	2	40	0.620
Salary, higher than 250 $ per month	67	60.4	57	58.8	0.815	70	70	3	60	0.639
Regular menstruation, yes	80	72.1	69	71.1	0.881	85	85	3	60	0.184

* Using Mann Whitney test

**Using χ^2 test, or Fisher's exact test as appropriate

Doctoral degree), and salary have been included in Table 1. There were no significant differences between groups (Table 1).

Healthy control subjects demonstrated a significantly elevated AHEI score (P-value < 0.001). The consumption of fruits, vegetables, and legumes was notably higher in these healthy controls (P-value < 0.001). Conversely, the intake of meat, trans fatty acids, fruit juice, and sodium was significantly greater in individuals with endometriosis (Table 2).

According to the Table 3, the crude model showed that those with the highest intake of fruits (gr/day, Odds Ratio (OR): 0.15, 95%Confidence interval (CI): 0.08, 0.29, P for trend < 0.001), vegetables (gr/day, OR: 0.05, 95%CI: 0.02, 0.13, P for trend < 0.001), and legumes (gr/day, OR: 0.26, 95%CI: 0.15, 0.46, P for trend < 0.001) had lower odds of endometriosis. Higher adherence to the AHEI was associated with a lower odds of endometriosis as shown in crude model (OR: 0.06, 95%CI: 0.02, 0.15, P for trend < 0.001). Conversely, the crude model showed direct

Table 2 Median (Q1-Q3) of the intakes of alternative healthy eating index components in patients with endometriosis and healthy control separately

	Healthy controls *N* = 208	Participants with endometriosis *N* = 105	*P*-value*
Fruits intake, grams/day	303.31 (163.27-570.58)	158.24 (107.05-232.45)	< 0.001
Vegetable's intake, grams/day	314.28 (168.48-469.59)	140.40 (83.55-207.21)	< 0.001
Legume's intake, grams/day	38.18 (20.00-66.94)	18.25 (8.51–33.89)	< 0.001
Poly unsaturated fatty acids intake, grams/day	19.30 (13.94–25.67)	19.96 (14.38–26.28)	0.480
Red and processed meats intake, grams/day	32.13 (17.49–51.64)	92.32 (62.17-141.29)	< 0.001
Sugar-sweetened beverages and fruit juice intake, grams/day	17.89 (6.76–57.50)	35.71 (1.68-190.59)	0.027
Trans fatty acids intake, grams/day	0.97 (0.59–1.47)	5.02 (2.01–10.66)	< 0.001
Sodium intake, milligrams/day	3089.06 (2362.63-4357.37)	3696.02 (2922.10-4962.62)	0.011
Alternative healthy eating index score**	49.34 (7.54)	33.57 (8.27)	< 0.001***

* Using Mann-Whitney test

** energy adjusted using residual method

*** Using independent samples T-test

All dietary components are reported as grams of intakes per day and sodium intake was reported in milligrams per day

association between intakes of meat (gr/day, OR: 10.67, 95%CI: 5.11, 22.25, P for trend < 0.001), trans fatty acids (gr/day, OR: 12.12, 95%CI: 5.61, 26.2, P for trend < 0.001) and sodium (gr/day, OR: 2.75, 95%CI: 1.65, 4.58, P for trend < 0.001) and odds of endometriosis. The results remained significant in both partially (Model 2) and fully adjusted models (Model 3) for fruits (gr/day, OR: 0.14, 95%CI: 0.06, 0.35, P for trend < 0.001), vegetables (gr/day, OR: 0.03, 95%CI: 0.01, 0.13, P for trend < 0.001) legumes (gr/day, OR: 0.23, 95%CI: 0.10, 0.51, P for trend < 0.001) and AHEI score (gr/day, OR: 0.08, 95%CI: 0.03, 0.24, P for trend < 0.001). High consumption of meat (gr/day, OR: 7.30, 95%CI: 2.82, 18.89, P for trend < 0.001), trans fatty acids (gr/day, OR: 7.32, 95%CI: 2.82, 18.97, P for trend < 0.001), and sodium (gr/day, OR: 2.30, 95%CI: 1.00, 5.28, P for trend = 0.049) remained risk factor for endometriosis in partially and fully adjusted models (Table 3).

In Table 4, the logistic regression model results indicated that with each unit increase in the AHEI score, the odds of endometriosis decreased by approximately 19%. Furthermore, a gram increase in the intake of fruits and vegetables corresponded to a 1% decrease in the odds of endometriosis. A gram increase in legume consumption resulted in a 3% decrease in the odds of endometriosis. Conversely, the intake of meat and fruit juice was associated with a 3% and 0.4% increase in the odds of endometriosis, respectively. Each unit increase in the consumption of trans fatty acids was linked to a 40% increase in the odds of endometriosis.

Discussion

The results of this study clearly showed that a higher adherence to the AHEI is associated with about 92% decrease in odds of endometriosis. Besides, with each unit increase in AHEI, the odds of developing endometriosis decreased by 19%. Additionally, it was shown that intakes of fruits, vegetables, and legumes were associated with a significant decrease in the odds of developing endometriosis, while intakes of meat and meat products, trans fatty acids, and probably higher intakes of sodium and sugar-sweetened beverages and fruit juices were associated with an increased odds of developing endometriosis in the participants. Similar to the results of our study, a recent cohort study has reported that adherence to the AHEI, is linked with a 13% lower risk of endometriosis diagnosis [13]. Previously, we observed that a fertility diet, emphasizing the consumption of vegetable proteins and multivitamins, is linked with a decreased odds of endometriosis by 66%, whereas a high glycemic load diet is associated with an increased odds [15]. Besides, a balanced diet rich in fruits, vegetables, and omega-3 fatty acids, is shown to be protective for endometriosis [27]. Diet plays its role by affecting immune and angiogenic processes, which are principal factors for the development of endometriosis [28, 29]. In addition, diet could potentially decrease the symptoms and improve the quality of life in patients with endometriosis; However, due to the complexity of dietary interactions and individual differences, more studies are needed [30].

Similarly, Mediterranean dietary pattern which shares similar dietary components with the AHEI, is shown to be associated with reduced pain in terms of dyspareunia, non-menstrual pelvic pain, dysuria and dyschezia [31]. The intervention with these kinds of anti-inflammatory dietary patterns for endometriosis patients is feasible, particularly when an intervention addresses identified barriers and facilitators [32].

We found that higher intakes of fruits and vegetables may be associated with a reduced odds of endometriosis. However, the association between fruits and vegetables and endometriosis seems to be controversial. Some studies represented a protective effect of vegetable consumption on endometriosis [33, 34], but interestingly, according to Harris et al., daily intake one or

Table 3 Alternative healthy eating index and its components and odds of endometriosis

Alternative healthy eating index components	Lower adherence to the Alternative healthy eating index	higher adherence to the Alternative healthy eating index	*P* for trend*
Fruits, gr/day	< 303 gr/day		
Number of healthy controls/cases	104/91	104/14	
Model 1	reference	**0.15 (0.08, 0.29)**	**< 0.001**
Model 2	reference	**0.09 (0.04, 0.19)**	**< 0.001**
Model 3	reference	**0.14 (0.06, 0.35)**	**< 0.001**
Vegetables, gr/day	< 315 gr/day		
Number of healthy controls/cases	104/100	104/5	
Model 1	reference	**0.05 (0.02, 0.13)**	**< 0.001**
Model 2	reference	**0.04 (0.01, 0.10)**	**< 0.001**
Model 3	reference	**0.03 (0.01, 0.13)**	**< 0.001**
Legumes, gr/day	< 38 gr/day		
Number of healthy controls/cases	104/83	104/22	
Model 1	reference	**0.26 (0.15, 0.46)**	**< 0.001**
Model 2	reference	**0.20 (0.11, 0.36)**	**< 0.001**
Model 3	reference	**0.23 (0.10, 0.51)**	**< 0.001**
Poly unsaturated fatty acids, gr/day	< 19 gr/day		
Number of healthy controls/cases	104/49	104/56	
Model 1	reference	1.14 (0.71, 1.83)	0.578
Model 2	reference	0.72 (0.41, 1.28)	0.270
Model 3	reference	0.82 (0.38, 1.73)	0.595
Red and processed meats, gr/day	< 32 gr/day		
Number of healthy controls/cases	104/9	104/96	
Model 1	reference	**10.67 (5.11, 22.25)**	**< 0.001**
Model 2	reference	**13.74 (6.06, 31.18)**	**< 0.001**
Model 3	reference	**7.30 (2.82, 18.89)**	**< 0.001**
Sugar-sweetened beverages and fruit juice, gr/day	< 18 gr/day		
Number of healthy controls/cases	104/42	104/63	
Model 1	reference	1.50 (0.93, 2.41)	0.095
Model 2	reference	1.28 (0.77, 2.13)	0.347
Model 3	reference	1.53 (0.76, 3.10)	0.237
Trans fatty acids, gr/day, crude	< 1 gr/day		
Number of healthy controls/cases	104/8	104/97	
Model 1	reference	**12.12 (5.61, 26.2)**	**< 0.001**
Model 2	reference	**17.68 (7.35, 42.58)**	**< 0.001**
Model 3	reference	**7.32 (2.82, 18.97)**	**< 0.001**
Sodium intake, mg/day, crude	< 3090 mg/day		
Number of healthy controls/cases	104/28	104/77	
Model 1	reference	**2.75 (1.65, 4.58)**	**< 0.001**
Model 2	reference	**2.32 (1.24, 4.33)**	**0.008**
Model 3	reference	**2.30 (1.00, 5.28)**	**0.049**
Healthy eating index, energy adjusted	< 54		
Number of healthy controls/cases	108/99	100/6	
Model 1	reference	**0.06 (0.02, 0.15)**	**< 0.001**
Model 2	reference	**0.04 (0.02, 0.12)**	**< 0.001**
Model 3	reference	**0.08 (0.03, 0.24)**	**< 0.001**

*Using logistic regression models

Model 1: crude

Model 2: adjusted for age, BMI (Kg/m2), total calories intake (Kcal/day)

Model 3: additionally adjusted for occupation, smoking (yes/no), age at menarche, menstruation duration, regular menstruation, familial history of endometriosis (yes/no) and physical activity (minutes/week)

All dietary components are reported as grams of intakes per day and sodium intake was reported in milligrams per day

Table 4 The association between alternative healthy eating index score and its components with odds of endometriosis

	Beta	Standard error	Wald	Degree of freedom	*P*-value	95% confidence interval for EXP(B)	
						Lower	Upper
Fruits intake, gr/day*	-0.01	0.001	45.410	1	**< 0.001**	0.992	0.996
Fruits intake, gr/day***	-0.01	0.001	18.550	1	**< 0.001**	0.993	0.997
Vegetable's intake, gr/day*	-0.01	0.001	56.525	1	**< 0.001**	0.987	0.993
Vegetable's intake, gr/day***	-0.01	0.002	26.151	1	**< 0.001**	0.988	0.995
Polyunsaturated fatty acids intake, gr/day*	-0.02	0.015	2.256	1	0.133	0.951	1.007
Polyunsaturated fatty acids intake, gr/day***	-0.03	0.019	1.862	1	0.172	0.938	1.012
Legume's intake, gr/day*	-0.04	0.006	38.095	1	**< 0.001**	0.950	0.974
Legume's intake, gr/day***	-0.03	0.008	17.055	1	**< 0.001**	0.954	0.983
Trans fatty acids intake, gr/day*	0.41	0.059	48.090	1	**< 0.001**	1.344	1.697
Trans fatty acids intake, gr/day***	0.39	0.075	27.760	1	**< 0.001**	1.280	1.714
Red and processed meats intake, gr/day*	0.03	0.004	57.243	1	**< 0.001**	1.025	1.043
Red and processed meats intake, gr/day***	0.03	0.006	29.51	1	**< 0.001**	1.020	1.042
Sugar-sweetened beverages and fruit juice intake, gr/day*	0.004	0.001	12.352	1	**< 0.001**	1.002	1.006
Sugar-sweetened beverages and fruit juice intake, gr/day***	0.004	0.001	7.365	1	**0.007**	1.001	1.007
Sodium intake, milligrams/day*	0.00	0.000	0.163	1	0.686	1.000	1.000
Sodium intake, milligrams/day***	0.00	0.000	0.006	1	0.941	1.000	1.000
Alternative healthy eating index score*	-0.223	0.026	74.470	1	**< 0.001**	0.761	0.842
Alternative healthy eating index score***	-0.19	0.030	42.124	1	**< 0.001**	0.779	0.875

* Energy adjusted using residual method

*** Adjusted based on age (years), occupation (yes/no), body mass index, BMI (Kg/m2), total calories intake (Kilocalories per day), smoking (yes/no), age at menarche (years), menstruation duration (days), regular menstruation (yes/no), familial history of endometriosis (yes/no), waist circumference and physical activity (minutes/week)

All dietary components are reported as grams of intakes per day and sodium intake was reported in milligrams per day

more servings of cruciferous vegetables, may potentially increase the risk of endometriosis, by 13%, compared to those ate less than one serving per week [35]. Furthermore, a meta-analysis showed no significant association between overall vegetables intake and the risk of developing endometriosis [36]. Regarding to fruits, Parazzini et al. showed that higher consumption of fruits and vegetables is associated with a reduced risk of endometriosis [34]. But conversely, Trabert et al., showed a direct relationship between increased fruit consumption and the chance of developing endometriosis [9]. So, there is a need for further research.

The protective role of fruits and vegetables may be due to their anti-inflammatory characteristics, which acts against the high level of C-reactive protein (CRP), and other inflammatory mediators including interleukin (IL)-6, IL1-β, and tumor necrosis factor alpha, and other oxidants, in patients with endometriosis. Besides, the antioxidant capacity of fruits and vegetables due to being rich source of vitamins E and C, reduces the production of CRP, reactive oxygen and nitrogen species [37]. As reported by a Randomized Clinical Trial, taking vitamin C (1000 mg/day) and vitamin E (800 IU/day) supplements, divided into two tablets each, led to a significant decrease in MDA and ROS levels compared to the placebo group. It also alleviated the severity of dysmenorrhea, dyspareunia, and pelvic pain in endometriosis patients [38]. The high fiber content and also B vitamins, and the presence of beta-cryptoxanthin in fruits, may represent its protective role [39–41]. Certain vegetables are also a good source of the antioxidant beta-cryptoxanthin, which has protective role for the risk of endometriosis [35]. In general, plant-based diets, due to their richness in antioxidants, vitamins A and C, and their effect on reducing inflammatory factors, can mitigate the severity and progression of endometriosis [42]. On the other hand, the adverse effects of some fruits and vegetables reported in studies may be due to the potential presence of organochlorines [43].

We confirmed previous findings that the consumption of meat products and trans fatty acids increases the odds of endometriosis [4, 13, 36, 44]. Yamamoto et al. showed that consuming more than 2 servings of red meat per day was associated with a 56% increase in the risk of developing endometriosis [45]. Consumption of more than two servings/day of red meat is shown to be associated with a 56% increased risk of endometriosis [45], which is proposed to due to the high amounts of trans fatty acids and saturated fats in red meat [36]. Missmer et al.'s longitudinal study showed that trans and unsaturated fatty acids are associated with endometriosis [8]. Increased consumption of trans fatty acids leads to a rise in circulating inflammatory factors such as IL-6 and markers of TNF system activation, which can increase the risk of

endometriosis due to their involvement in its pathogenesis [46–48]. The high amounts of dietary advanced glycation end-products in red meat increases the CRP and white blood cells levels as inflammatory markers [49, 50]. Increased intake of heme-iron in red meat may potentially induce the oxidizing effect of iron in the body by increasing the reactive oxygen species [51]. This could damage DNA and play a negative role in epithelial cell proliferation [52] and worsen the uterine lesions that occur in endometriosis [53]. Furthermore, increased red meat intake is linked to lower sex hormone-binding globulin levels and higher estradiol concentrations, and elevated estrogen levels can worsen inflammatory conditions [54, 55]. An increase in endogenous estrogen can, in turn, lead to increased stimulation of prostaglandin formation and consequently contribute to the inflammatory components of endometriosis, which increases the risk of development and progression for the disease [56]. Although some evidence indicates no relationship between meat consumption and the risk of developing endometriosis [9].

Our research indicates that consuming legumes may have a protective effect against endometriosis. Consistent with our findings, it has been shown that consuming two or more servings of grain legumes per week leads to a lower risk of developing endometriosis compared to those with lower consumption levels [33]. Although, according to a meta-analysis, there is not any significant association between legumes and endometriosis [36]. Legumes are a good source of non-animal dietary protein, fiber and phytoestrogen sources [57]. Increasing the intake of fiber, reduces the amount of circulating estrogen [58], and on the other hand, increasing the intake of dietary phytoestrogens through legumes, can balance the circulating amount of estrogen through binding to estrogen receptors with their selective binding properties [59], and also plays its protective role through reversing cell proliferation and modifying the inflammatory mediators [60]. Besides, the high fiber intake regulates insulin levels and reduces inflammation, both of which are relevant factors in the development of endometriosis [61]. There is an indirect link between intake of phytoestrogens, particularly isoflavones and lignans found in legumes, with the risk of endometriosis [61]. Phytoestrogens may play the protective role by affecting inflammatory responses and hormonal levels [61].

We have also found a direct association between sodium intake and endometriosis. Research suggests that sodium-potassium-chloride cotransporters (NKCC1, NKCC2) are highly expressed in ectopic endometrial tissues, indicating that sodium transport mechanisms might contribute to the pathology of endometriosis [62]. The increased expression of these transporters is associated with the size of endometriomas, implying a potential connection between sodium dynamics and the severity of the disease [62]. may affect endometriosis through mechanisms such as inflammation and oxidative stress [53, 63].

Finally, we showed that deleterious effect of sugary beverages and fruit juice, which is a source of simple sugar, on the odds of endometriosis. Although direct studies on sugar intake and endometriosis are limited, research has shown that high sugar consumption is associated with an increased risk of endometrial cancer. This association may suggest a broader link between sugar intake and reproductive health issues, including endometriosis, due to shared pathways involving insulin and inflammation [64, 65]. The link between simple sugar intake and endometriosis is an emerging area of research, particularly due to sugar's role in promoting insulin production and its potential connections to inflammation and hormonal imbalances. High consumption of simple sugars, especially added sugars, can elevate insulin levels. Insulin resistance and hyperinsulinemia have been linked to various reproductive health issues, including endometriosis. Elevated insulin levels can stimulate ovarian function and increase estrogen production, potentially worsening endometriosis symptoms and progression [64, 65]. Excessive sugar intake is associated with low-grade chronic inflammation, a known factor in the pathogenesis of endometriosis. Sugars can promote the release of inflammatory cytokines, potentially exacerbating the inflammatory environment linked to endometriosis [66].

Our study included multiple advantages. This study was one of the initial inquiries that explored the association between AHEI and the likelihood of developing endometriosis. The AHEI represents a composite measure that considers multiple dietary components as a single dietary pattern. This approach inherently accounts for correlations and interactions between individual dietary components, thus reducing the concern of multicollinearity among variables. Additionally, by summing the scores of individual components into a single index, the statistical model is simplified, avoiding the inclusion of highly correlated independent variables in the logistic regression analysis [67]. A validated FFQ was used to obtain data on usual dietary intakes of participants. We ensured that the FFQ was administered using a standardized protocol across all participants to reduce inconsistencies. The interviewer underwent rigorous training before the study to ensure uniformity in the data collection process. The FFQ used in our study has been validated previously in an Iranian population, ensuring its reliability and accuracy for capturing dietary intake data. This step helps reduce measurement errors [16]. To help participants recall their typical dietary intake more accurately, we used portion size photographs and local food models during the FFQ interviews. This approach has been

shown to improve the accuracy of dietary data collection. In addition, several confounders were adjusted for in the final analysis to reach an independent association AHEI and endometriosis. Both groups had high participation rates, and to maintain data integrity, we excluded participants who reported inaccurate or excessive energy intake, as well as those who had not been diagnosed within the past six months. By selecting incident cases, we reduced recall bias and improved the interpretation of causal relationships. Interviews were conducted by a professional dietitian who was blinded to the participants' diagnostic status. To minimize interviewer bias, the trained dietitians administering the FFQ were blinded to the case or control status of the participants. The participants were only identified by study ID numbers, and their group status was not disclosed during data collection. However, our study had some limitations. The omission of wine, long-chain omega-3 fatty acids, and whole grains from the AHEI score calculation reflects an adaptation of the index to the cultural and dietary context of Iran. This may slightly limit the comparability of our results to studies conducted in populations where these components are integral to the diet. However, the remaining components of the AHEI still capture important dimensions of dietary quality and are valid indicators of adherence to a healthy eating pattern within the Iranian population. It is possible that knowing about an endometriosis diagnosis before completing the FFQ may have influenced dietary recall differently for the case group compared to the control group. Despite efforts to minimize bias, certain biases such as selection bias, recall bias, and measurement bias could still lead to misleading conclusions in a case-control study. Another limitation was the lack of clinical stage data for all participants, which could impact understanding the relationship between dietary habits and disease progression in endometriosis patients. Additionally, the exclusion of data on infertility and the use of assisted reproductive technologies was another limitation.

Conclusion

In conclusion, our study clearly showed that improving diet quality by consuming fruits, vegetables, and legumes, as captured by higher AHEI, is associated with a reduced odds of developing endometriosis. On the other hand, the chance of developing endometriosis increased with higher consumption of meat products and trans fatty acids, therefore, limiting consumption is recommended. Finally, due to the impact of diet quality on the risk of developing endometriosis, it is suggested that dietary patterns rich in antioxidants and vitamins, be utilized to prevent the development and progression of the disease.

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Author contributions
GE: conceptualization and supervision. MN, SMG, SG, FSHJ and GE: data curation and writing—review and editing. SNK and RT: investigation. MN, SMG, GE, BR and SNK: methodology. MN, SMG, and GE: software, formal analysis, and writing—original draft preparation. SNK and BR: visualization. RT and BR: validation. All authors contributed to the article and approved the submitted version.

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Data availability
The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by Medical Ethical Committee of National Nutrition and Food Technology Research Institute of Shahid Beheshti University of Medical Sciences (IR.SBMU.NNFTRI.REC.1399.062), in Iran, according to the Declaration of Helsinki. All of the participants provided written informed consent. Data confidentiality was also ensured.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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