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The association between the planetary health diet index and the risk of sarcopenia and protein-energy wasting in patients with chronic kidney disease

Fatemeh Mansouri[1], Zainab Shateri[2], Marzieh Shoja[3], Shahrokh Ezzatzadegan Jahromi[4], Mehran Nouri[5*] and Siavash Babajafari[1,6*]

Abstract

Background The Planetary Health Diet Index (PHDI) is a dietary index that emphasizes plant sources and recommends reducing animal-source food consumption. The relationship between this index and chronic kidney disease (CKD) has not been studied. This study aimed to examine the association between sarcopenia and protein-energy wasting (PEW) with PHDI in CKD patients.

Methods The present study was a cross-sectional one, conducted in Shiraz, Fars province, Iran. Patients were selected from Motahari and Imam Reza clinics between January to October 2022. The guideline of the Asian Working Group for Sarcopenia (AWGS) was used to assess sarcopenia. PEW was identified based on the four criteria of the International Society of Renal Nutrition and Metabolism (ISRNM). PHDI was calculated according to the reference diet suggested by the EAT-Lancet Commission. Logistic regression was used to evaluate the association between PHDI and odds ratio (OR) of sarcopenia and PEW.

Results In the multivariable analysis, in both crude and adjusted models, no significant association was seen between a unit change in the PHDI score and the odds of sarcopenia and PEW ($P > 0.05$ for both). In comparison to scores lower than the mean of PHDI score, in the crude model, no significant association was found between scores higher than the mean of PHDI score and sarcopenia and PEW. However, in the adjusted model, the odds of sarcopenia were significantly lower in participants with a PHDI score higher than the mean compared to those with a PHDI score lower than the mean of (OR = 0.249, 95% confidence interval (CI): 0.070–0.881, $P = 0.031$).

Conclusion This study showed that a high adherence to PHDI is associated with a reduced odds of sarcopenia in CKD patients. However, it did not have a significant effect on reducing the odds of PEW in these patients.

Co-corresponding Author: Mehran Nouri

*Correspondence:
Mehran Nouri
mehran.nouri71@gmail.com
Siavash Babajafari
jafari@sums.ac.ir

Full list of author information is available at the end of the article

Keywords Planetary health diet index, Sarcopenia, Protein-energy wasting, Chronic kidney disease

Introduction

Chronic kidney disease (CKD) is a condition that primarily affects adults, particularly those with hypertension and diabetes. This disease is incurable and is associated with a high mortality rate and significant complications [1]. One of the most common complication of CKD is the loss of muscle mass, known as sarcopenia [2, 3]. Sarcopenia develops due to various nutritional and metabolic abnormalities, leading to impaired skeletal muscle mass and function [4].

Another complication of CKD is protein-energy wasting (PEW), which is characterized by a reduction in fat mass, decreased circulating protein levels, or a decline in overall body protein mass [5]. PEW results from various mechanisms in CKD, including systemic inflammation, hormonal imbalances, malnutrition, uremic toxicity, and comorbidities [6]. Numerous studies have demonstrated that PEW is associated with unfavorable clinical outcomes, including increased mortality and hospitalization rates [7, 8].

Nutritional status and diet play a crucial role in CKD management, as the declining kidney function significantly impacts metabolism [9]. Maintaining optimal nutritional status and implementing dietary interventions can help slow disease progression and reduce the burden of CKD [9]. In patients with CKD, strategies aimed at improving nutritional status and addressing sarcopenia and wasting can be life-saving, potentially offering greater benefits than conventional approaches targeting conditions such as hypertension, high cholesterol, and obesity [10].

The human diet has undergone significant changes in recent decades, driven by shifts in agricultural systems, globalization, and technological advancements. In response of these changes, the concept of a healthy diet has evolved to incorporate considerations of planetary health [11]. The Planetary Health Diet (PHD), introduced by the EAT-Lancet Commission, represents a sustainable and health-promoting dietary approach designed to benefit both human and the environment [12]. This dietary framework emphasizes a higher intake of whole grains, fruits, and vegetables while advocating for a reduced consumption of refined grains, meat, fish, eggs, and tubers [12]. The Planetary Health Diet Index (PHDI) serves as a measure of adherence to this dietary pattern and is positively associated with carbohydrates, fiber, polyunsaturated fatty acids (PUFA), vegetable protein, and various micronutrients found in vegetables, fruits, whole grains, and oilseeds [12].

To date, no studies have examined the association between PHDI and CKD patients, although research suggests that plant-based diets may influence the management of advanced CKD. Several mechanisms, including improved acid-base balance, better nitrogen metabolism, reduced acid load, lower salt intake, and decreased production of uremic toxins, may explain the potential benefits of a plant-based diet in CKD treatment [13]. Acidemia in CKD patients contributes to increased insulin resistance and elevated glucocorticoid levels, which play a role in the development of PEW [7]. Additionally, addressing metabolic acidosis is essential for preventing sarcopenia and preserving muscle mass [14]. Therefore, a plant-based diet may mitigate in PEW and sarcopenia. However, some reports suggest potential adverse effects of plant-based diets on sarcopenia and PEW [15].

Since the PHDI prioritizes plant-based sources and promotes a reduced animal-derived foods, its association with two major complications of CKD remains unexplored. Therefore, this study aimed to investigate the relationship between PHDI, sarcopenia and PEW patients.

Methods

Study population

The present study was designed as a cross-sectional investigation in Shiraz, located in the Fars province, Iran. Patients were recruited from Motahari and Imam Reza clinics between January and October 2022. The sample size estimated based on a proportion (p) of 0.5, a margin of error (d) of 0.1, and a significance level (α) of 0.05, resulting a required sample size of 97. To account for potential dropouts, a total of 109 patients were ultimately included in the study.

According to the inclusion criteria, the present study included 109 patients aged 18 years or older, who no cognitive impairments and a glomerular filtration rate (GFR) of less than 60 mL/min/1.73 m^2. Patients with heart failure, those consuming fewer than 800 or more than 4200 kcal/day, and individuals who answered less than 60% of the questions were excluded from the study.

This study was approved by the Medical Research and Ethics Committee of Shiraz University of Medical Sciences (IR.SUMS.SCHEANUT.REC.1402.060). Some details of the study have been published previously [16–18].

Data collection

Bioelectrical impedance analysis (BIA) using the IN BODY-S10 device was conducted to assess muscle and fat mass percentage. Weight was measured with a precision of 100 g, with participants wearing minimal clothing and no shoes. Height and mid-arm circumference (MAC)

were recorded with a precision of 0.5 cm. Additionally, body mass index (BMI) was calculated. Physical activity levels were assessed using the validated International Physical Activity Questionnaire (IPAQ) [19].

Biochemical assessment

For laboratory evaluations, a 15-milliliter blood sample (5 mL for blood gases and 10 mL for albumin and other biomarkers) was collected from each participant at Raz Laboratory in Shiraz after 10 to 14 h of fasting. Blood gas analysis was performed using an autoanalyzer with a Technomedica device. Blood albumin levels and other biomarkers were measured using a Mindray device (manufactured in Japan) with Pars Azmoon kits.

Sarcopenia diagnosis

The Asian Working Group for Sarcopenia (AWGS) guidelines were utilized to assess muscle mass, strength, and function. Muscle strength was evaluated by measuring handgrip strength (HGS) using a dynamometer. Muscle function was assessed through gait speed (measuring walking speed over a 6-meter distance) and the five-time chair standing test. Muscle and fat mass were measured by BIA. The Skeletal Muscle Index (SMI) was calculated as skeletal muscle mass (ASM) divided by height squared. An SMI of less than 7 kg/m^2 for men or less than 5.7 kg/m^2 for women was considered the primary criterion for diagnosing sarcopenia. Subsequently, low physical performance (gait speed < 1 m/s or a 5-time chair standing test during ≥ 12 s) and/or reduced muscle strength (< 28 kg for men and 18 kg for women) were assessed to confirm the diagnosis of sarcopenia [20, 21].

Protein-energy wasting (PEW) diagnosis

PEW was identified based on four criteria outlined by the International Society of Renal Nutrition and Metabolism (ISRNM), including protein intake of less than 0.6 g/kg/day, a BMI less than 23 kg/m2, biochemical markers such as serum albumin < 3.8 g/dL, and the lowest quartile of 24-hour urine creatinine excretion (UCE) stratified by sex. The presence of three or more of these criteria was considered indicative of PEW [22].

Dietary assessments

The participants' dietary intake was assessed using a validated 168-item food frequency questionnaire (FFQ) [23]. Portion sizes of food items were then converted to grams and multiplied by their daily intake frequency. Finally, the total intake of each item was calculated.

The PHDI is based on the reference diet recommended by the EAT-Lancet Commission [12]. It includes all EAT-Lancet food groups and employs a progressive scoring system, where components are scored based on consumption level. The index contains of 16 components categorized into four groups:

- **Adequacy components**: fruits, total vegetables, nuts and peanuts, legumes, and whole cereals.
- **Optimum components**: eggs, fish and seafood, dairy products, vegetable oils, tubers, and potatoes.
- **Ratio components**: red and orange vegetables/total vegetables and dark green vegetables/total vegetables.
- **Moderation components**: red meat, animal fats, added sugar, chickens, and substitutes.

Components in the adequacy, optimum, and moderation categories are scored between 0 and 10 points, while ratio components are scored between 0 and 5 points. The total PHDI score ranges from 0 to 150 points [24, 25]. Further details on scoring criteria and cutoff points can be found in Cacau et al. [11].

Statistical analysis

Statistical analysis was conducted using SPSS software (version 26). Descriptive statistics were used to summarize continuous variables as mean and standard deviation (SD) or median and interquartile range (IQR), while categorical variables were described using frequencies and percentages.

Logistic regression analysis was performed to assess the association between PHDI and the odds ratio (OR) of sarcopenia and PEW under both continues and categorical conditions. In the adjusted model, analysis was controlled for age, sex, smoking, fat and energy intake were adjusted. A p-value < 0.05 was considered statistically significant.

Results

Significant differences were observed in age ($P = 0.002$), BMI ($P = 0.034$), fat percentage ($P = 0.044$), physical activity ($P = 0.016$), high-density lipoprotein cholesterol (HDL-C) ($P = 0.036$), total PHDI score ($P < 0.001$), and its adequacy ($P < 0.001$), optimum ($P < 0.001$), ratio ($P = 0.040$), and moderation ($P < 0.001$) components between participants with PHDI scores lower and higher than the mean (Table 1).

Macronutrient intake across the mean PHDI score is shown in Table 2. The intake of carbohydrates, protein, saturated fatty acid (SFA), and monounsaturated fatty acid (MUFA) did not differ significantly between PHDI categories. However, PUFA intake was significantly higher in participants with PHDI score above the mean ($P = 0.005$).

In the multivariable analysis (Table 3), both crude and adjusted models showed no significant association

Table 1 Baseline features of study population across the median of planetary healthy diet index

Variables	PHDI		
	Lower than the median score (n = 58)	Higher than the median score (n = 51)	P-value
Age (year) [1]	61.00 (22.00)	68.00 (14.00)	**0.002**
BMI (kg/m^2)[2]	26.91 ± 5.71	29.20 ± 5.38	**0.034**
Sarcopenia, yes (%) [3]	11 (19.00)	5 (9.80)	0.278
PEW, yes (%) [3]	9 (15.50)	6 (11.80)	0.781
Sex, male (%) [3]	31 (53.40)	28 (54.90)	0.999
Muscle weight (kg) [1]	20.15 (7.50)	21.60 (8.60)	0.274
Fat percentage (%) [2]	25.48 ± 9.88	29.20 ± 9.01	**0.044**
MAC (cm) [1]	28.50 (5.00)	30.00 (4.00)	0.079
ASM (kg/m^2) [2]	8.07 ± 1.61	8.50 ± 1.37	0.147
HGS (kg) [1]	16.50 (10.00)	19.00 (11.00)	0.459
Walk duration (second) [1]	7.00 (2.00)	7.00 (1.50)	0.112
Chair sitting (second) [1]	14.00 (5.00)	14.00 (3.00)	0.289
SGA [1]	9.50 (4.00)	9.00 (3.00)	0.165
Smoking, yes (%) [3]	11 (19.00)	12 (23.50)	0.641
Physical activity (%) [3]	36 (62.10)	42 (82.40)	**0.021**
Low	22 (37.90)	9 (17.60)	
Moderate			
Marital status (%) [3]	6 (10.30)	1 (2.00)	0.118
Single	52 (89.70)	50 (98.00)	
Married			
GFR (mL/min/1.7m^2) [2]	32.44 ± 14.08	32.60 ± 12.89	0.950
Hemoglobin (gr/dL) [2]	12.24 ± 1.95	12.87 ± 2.34	0.132
Albumin (gr/dL) [2]	4.09 ± 0.45	4.10 ± 0.38	0.880
Iron (µg/dL) [2]	73.39 ± 28.49	71.95 ± 40.70	0.853
Ferritin (ng/ml) [2]	139.85 ± 153.28	112.20 ± 84.83	0.268
TIBC (mcg/dl) [1]	321.50 (76.00)	227.00 (86.00)	0.173
ALT (IU/L) [2]	21.87 ± 9.21	22.56 ± 11.23	0.763
AST (IU/L) [1]	21.00 (9.00)	20.00 (8.00)	0.660
PTH (pg/mL) [1]	55.90 (95.00)	70.60 (58.50)	0.217
Vitamin D_3 level (ng/mL) [2]	33.78 ± 14.37	36.09 ± 16.25	0.441
BUN (mg/dl) [2]	34.28 ± 16.87	29.69 ± 13.15	0.120
Creatinine (mg/dL) [1]	1.98 (1.50)	2.00(.70)	0.535
Urine creatinine (mg/dL) [2]	847.51 ± 416.34	903.76 ± 367.64	0.459
FBS (mg/dL) [1]	99.50 (35.00)	96.00 (35.00)	0.762
TG (mg/dL) [2]	146.04 ± 90.30	155.00 ± 90.18	0.637
Total cholesterol (mg/dL) [2]	153.72 ± 41.67	148.96 ± 35.28	0.524
LDL-C(mg/dL) [2]	84.15 ± 27.27	83.41 ± 26.21	0.898
HDL-C (mg/dL) [2]	45.38 ± 15.00	39.63 ± 8.77	**0.036**
PCO_2 (mmHg) [2]	41.32 ± 8.91	47.73 ± 56.07	0.392
PO_2 (mmHg) [1]	38.05 (25.00)	30.80 (15.90)	0.508
HCO_3 (mmol/L) [2]	22.86 ± 3.43	22.22 ± 3.78	0.353
PHDI total score [2]	62.24 ± 8.03	84.80 ± 7.60	<**0.001**
PHDI adequacy components [1]	23.00 (14.25)	30.00 (12.00)	<**0.001**
PHDI optimum components [1]	22.00 (9.25)	28.00 (7.00)	<**0.001**

BMI: body mass index, PEW: protein-energy wasting, MAC: mid-arm circumference, ASM: appendicular skeletal muscle mass, HGS: handgrip strength, SGA: subjective global assessment, GFR: glomerular filtration rate, TIBC: total iron-binding capacity, ALT: alanine transaminase, AST: aspartate transaminase, PTH: parathyroid hormone, BUN: blood urea nitrogen, FBS: fasting blood sugar, TG: triglyceride, LDL-C: low-density lipoprotein cholesterol, HDL-C: high-density lipoprotein cholesterol, PCO2: partial pressure of carbon dioxide, PO_2: partial pressure of oxygen, PHDI: planetary healthy diet index

[1] Using Mann–Whitney U test for abnormal continuous variables and values are median (IQR)

[2] Using independent samples T-test for normal continuous variables and values are mean ± SD

[3] Using chi-square test for categorical variables and values are percentage

Table 2 The contribution of macronutrient and planetary healthy diet index components intake based on the median score of planetary healthy diet index

Variables	PHDI		
	Lower than the median score (*n* = 58)	Higher than the median score (*n* = 51)	*P*-value
Carbohydrates (% energy/day)	66.47 ± 6.19	66.67 ± 5.09	0.761
Protein (% energy/day)	11.84 ± 1.51	11.75 ± 1.62	0.858
SFA (% energy/day)	7.93 ± 3.19	7.22 ± 2.73	0.218
MUFA (% energy/day)	8.01 ± 2.46	8.41 ± 2.73	0.417
PUFA (% energy/day)	5.23 ± 1.22	5.94 ± 1.38	**0.005**

PHDI: planetary healthy diet index, SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids

Using independent samples T-test for normal continuous variables and values are mean ± SD

between a unit change in the PHDI score and the odds of sarcopenia or PEW ($P > 0.05$ for both).

In the crude model, no significant association were found between higher a PHDI score higher than the mean and the odds of sarcopenia and PEW compared to those with a PHDI score lower than the mean. However, in the adjusted model, the odds of sarcopenia were significantly lower in participants with a PHDI score higher than the mean compared to those with a PHDI score lower than the mean (OR = 0.249, 95% confidence interval (CI): 0.070–0.881, $P = 0.031$).

Discussion

The present study demonstrated that greater adherence to the PHDI was associated with reduced odds of sarcopenia in CKD patients. However, no significant association was observed between PHDI and the odds of PEW in these patients.

The interplay between human health, climate change, and food systems has been widely discussed in recent years [26]. The release of the 2019 EAT-Lancet Commission report aimed to address global challenges related to planetary and dietary sustainability [12]. The EAT-Lancet diet, highlighted in the report, promotes a plant-based dietary approach characterized by low intake of saturated fat, animal products, and sugar, while encouraging higher consumption of nuts, legumes, fruits, whole grains, and vegetables [27]. The PHD aligns with these principles, featuring a significant proportion of whole grains, which contribute to its high fiber content. Increasing whole grain consumption is a commonly recommended strategy to enhance fiber intake and promote better health outcomes [28].

The findings of this study suggest that adherence to the PHDI is associated with a reduced likelihood of sarcopenia in individuals with CKD. The prevalence of sarcopenia among CKD patients is influenced by factors such as disease progression, comorbidities, and associated complications [29]. Previous research indicates that approximately one-third of CKD patients experience sarcopenia [9]. The underlying mechanisms contributing to sarcopenia in CKD include metabolic acidosis, disruptions in protein metabolism, malnutrition, and systemic inflammation [30, 31].

Plant-based diets have been shown in mitigate inflammation in CKD patients [32]. The high fiber content of the PHD may contribute to this anti-inflammatory effect through multiple mechanisms [33]. Increased fiber intake has been associated with higher levels of the anti-inflammatory adiponectin and reduced absorption of colonic bacterial toxins, such as indoles, phenols, and amines. By limiting the absorption and production of these toxins, fiber intake may help alleviate systemic inflammation [34].

Metabolic acidosis, a major complication of CKD, is also a contributing factor to the development of sarcopenia. Studies indicate that metabolic acidosis in CKD

Table 3 The association between planetary healthy diet index with the risk of sarcopenia and protein-energy wasting

Median of PHDI	Abnormal/normal	Crude Model			Adjusted Model		
		OR	95% CI	*P*-value	OR	95% CI	*P*-value
Sarcopenia							
Continuous PHDI score	16/93	1.009	0.968–1.052	0.671	0.995	0.952–1.040	0.824
Lower than the median score of PHDI (≤ 74)	11/47	Ref.	-		Ref.	-	
Higher than the median score of PHDI (˃ 74)	5/46	0.464	0.150–1.441	0.184	**0.249**	**0.070–0.881**	**0.031**
Protein-energy wasting							
Continuous PHDI score	15/94	1.011	0.969–1.055	0.619	1.008	0.966–1.053	0.709
Lower than the median score of PHDI (≤ 74)	9/49	Ref.	-		Ref.	-	
Higher than the median score of PHDI (˃ 74)	6/45	0.726	0.239–2.201	0.571	0.576	0.171–1.940	0.373

PHDI: planetary healthy diet index, OR: odds ratio, CI: confidence interval

Obtained from logistic regression

These values are odds ratio (95% CIs)

Significant values are shown in bold

Adjusted for age, sex, smoking, fat and energy intake

patients is associated with elevated levels of C-reactive protein (CRP), a key marker of inflammation [35]. Higher fiber intake has been linked to lower CRP levels in CKD patients, suggesting a potential role for fiber-rich diets, in reducing sarcopenia risk through these mechanisms [32].

The study findings did not demonstrate a significant association between adherence to the PHDI and the presence of PEW in individuals with CKD. Patients with CKD and PEW have distinct dietary requirements, particularly regarding energy intake, protein quantity, and protein quantity [36].

For CKD patients, adequate energy and protein intake are essential to prevent PEW, with recommended levels typically ranging from 30 to 35 kcal/kg and 0.6–0.8 g/kg of ideal body weight per day, respectively. However, it is important to note that the recommended dietary allowance (RDA) for protein is often based on high-quality animal-derived protein sources [37]. While plant-based proteins are beneficial, a higher intake may be required to meet protein needs due to their lower biological value and limited amounts of certain essential amino acids [37].

Plant-based diets, including the PHD, may lack sufficient amounts of essential amino acids such as lysine, methionine, cysteine, and branched-chain amino acids (valine, leucine, and isoleucine) compared to animal-based diets [37]. Supplementation with specific amino acids, particularly leucine, has been shown to help mitigate muscle wasting in CKD patients [38]. Moreover, a study indicate that animal-based proteins may be more effective in stimulating myofibrillar protein synthesis than plant-based proteins, particularly in healthy older adults [39].

While plant-based diets like the PHD provide benefits such as enhanced intestinal health, greater dietary diversity, and a lower risk of metabolic disorders, they may also have a lower energy density, potentially leading to reduced total energy intake [13, 40]. This decrease in energy intake may be partly due to fiber fermentation by the gut microbiome [27], which generates short-chain fatty acids like acetate, known to suppress appetite [41, 42].

Acetate can influence appetite both directly and indirectly. It stimulates the production of peptide YY and glucagon-like peptide-1 (GLP-1), both of which contribute to appetite suppression [41, 42], ultimately leading to reduced energy intake. However, plant-based diets have offer several benefits, including improved gut health and function, increased dietary diversity, reduced metabolic disorders, and lower acid load [43]. It appears that these positive and negative attributes of plant-based diets, such as the PHD, may counterbalance each other, which could explain why adherence to this diet did not significantly impact the likelihood of PEW in CKD patients.

This study is the first to examine the association between the PHDI and the odds of sarcopenia and PEW in individuals with CKD. A key strength of this research was the rigorous control of confounding variables the relationship between PHDI, sarcopenia, PEW. However, due to the novelty of this topic and the limited existing literature, comparing these findings with previous research to validate the results remains challenging. Additionally, the relatively small sample size may have influenced the statistical power of the study. Furthermore, the cross-sectional design introduces inherent limitations, including recall bias and selection bias, which restrict causal inference. While this study provides an important foundation for exploring the link between the PHDI and two critical complications of CKD, further research is necessary to confirm and clarify the underlying mechanisms of this dietary pattern.

Conclusions

The findings of this study indicate that high adherence to the PHDI is associated with a lower likelihood sarcopenia in individuals with CKD. However, no significant relationship was observed between PHDI adherence and the odds of PEW in CKD patients. Further research is required to thoroughly investigate the association between PHDI and these two major complications of CKD, offering deeper insights into the potential role of dietary interventions in managing CKD-related complications.

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Author contributions
F.M., Z.S., M.S., S.E.J. and M.N.; Contributed to writing the first draft. M.N.; Contributed to all data, statistical analysis, and interpretation of data. F.M and S.B.; Contributed to the research concept, supervised the work, and revised the manuscript. All authors read and approved of the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethical approval and consent to participate
this study was approved by the medical research and ethics committee of Shiraz University of Medical Science and the informed consents were completed by all participants. Also, we confirmed all the methods included in this study are in accordance with the declaration of Helsinki.

Consent for publication
not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Clinical Nutrition, School of Nutrition and Food Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Department of Nutrition and Biochemistry, Faculty of Medicine, Ilam University of Medical Sciences, Ilam, Iran
[3]Nutrition and Metabolic Diseases Research Center and Clinical Sciences Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[4]Department of Medicine, School of Medicine, Shiraz Nephro-Urology Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
[5]Infertility and Reproductive Health Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, Iran
[6]Nutrition Research Center, Department of Clinical Nutrition, School of Nutrition and Food Science, Shiraz University of Medical Sciences, Shiraz, Iran

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