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Association of Nutrient Patterns and Their Relation with Obesity in Iranian Adults: a Population Based Study

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ABSTRACT

In the present research, we have evaluated the association between patterns of nutrient intake and obesity. The present cross-sectional study recruited 850 adults aged between 20–59 years old. Dietary intakes were assessed with three 24-hour recalls. As well, data on anthropometric measures were collected. General obesity was specified as body mass index ≥ 30 kg/m². Factor analysis was conducted, and followed by a varimax rotation, was performed to extract major nutrient patterns. Our analysis identified three major nutrient patterns: The first nutrient pattern was characterized by the high consumption of saturated fatty acids (SFAs), protein, vitamins B_1, B_2, B_6, B_5, B_3, B_{12}, Zinc, and iron. The second nutrient pattern was rich in total fat, polyunsaturated fatty acids, monounsaturated fatty acids, SFAs, oleic acid, linolenic acid, zinc, vitamin E, α-tocopherol, and β-carotene. The third one was greatly loaded with protein, carbohydrate, potassium, magnesium, phosphorus, calcium, vitamin C, and folate. Women in the third quintile of the first pattern were less likely to be generally obese in the fully adjusted model (odds ratio, 0.44; 95% confidence interval, 0.25–0.75). None of the other nutrient patterns had a significant association with obesity, even after adjusting for confounders. Adherence to a nutrient pattern rich in water-soluble vitamins was significantly associated with a greater chance of general obesity among women. Further studies in other populations, along with future prospective studies, are required to confirm these findings.

Keywords: Anthropometry; Obesity; Nutrients; Factor analysis

INTRODUCTION

Obesity and overweight are known as major public health concerns which its prevalence is on the rise with an alarming rate in both developed and developing countries [1]. The World Health Organization (WHO) reported that in 2016, 39% and 13% of adults in the world were overweight and obese, respectively [1]. In Iranian adults, its prevalence has increased from 12.6%–25.9% from 2007 to 2014 [2]. Overweight and obesity are specified as abnormal or

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Conflict of Interest

The authors declare that they have no competing interests.

extreme fat accumulation in the body [3]. Obesity is one of the preventable risk factors for global deaths and is considered a crucial risk factor for several chronic diseases, including diabetes, cardiovascular diseases (CVD), and some kind of cancer [1].

Some studies showed a positive linkage between some nutrients, mainly dietary fat, [4] carbohydrates [5], and the odds of obesity, while others reported an inverse link between consumption of dietary proteins, [6] fiber, [7] individual micronutrients such as vitamins A, B, C [8,9] and D [10], and minerals, such as calcium [11], with obesity. Dietary patterns (DPs) provide a clear insight into diet-disease relations [12] the effects from single nutrients or foods may be minor to be measurable, while there may be major associations between DPs and risk of obesity and its complication [13]. Although food patterns can predict the risk of chronic conditions, the exact mechanisms through which these patterns might alter the risk are not well known. Food patterns affect the risk of chronic conditions through nutrient intakes. It seems a combination of nutrients, rather than a single nutrient, probably will influence the risk [14-21]. Therefore, nutrient patterns may provide more evidence about possible underlying mechanisms. In contrast to food patterns, some studies have shown a relation between nutrient patterns and chronic diseases [14-21]. Reports indicated associations between nutrient patterns with other chronic conditions such as osteoporosis and some cancers [14-16,18-21] or, for instance, nutrient patterns with high antioxidants [14], or vitamins and fiber [16], may prevent some cancers. High intake of proteins, unsaturated fats, calcium, phosphorus, vitamin B12, and moderate alcohol has been related to with a lower risk of wrist and hip fractures [21].

Healthy DPs such as, the Mediterranean diet that is considered as a diet with high consumption of whole grains, fruits, vegetables, and fish were associated with favorable effects on metabolic disorders [22]. Earlier study demonstrated that a nutrient pattern which is high in selenium, calcium, iron, manganese, folate, betaine, thiamine, niacin, and starch lowered the risk of general obesity, while adherence to a pattern with high amounts of total dietary fiber, glucose, fructose, sucrose, potassium, copper, vitamin C and vitamin K was positively associated with general obesity in men, but not in women [23].

Investigating patterns of nutrient intake to provide insights into combinations of nutrients might have the effect on the obesity risk. Dietary patterns can vary depending on the geographical environment, food culture, and economic habits, so dietary habits could be substantially different in any region. Therefore, the aim of study was to examine the association of nutrient patterns and obesity as a prevalent condition.

MATERIALS AND METHODS

Study design

In this cross-sectional study, we included 850 seemingly healthy adults in the age range of 20 to 59 years. Participants were selected by cluster sampling from 5 geographical areas in Tehran. In this way, several health homes were selected from each area, and then easy sampling was performed. This study has been carried out according to the guidelines of the Helsinki Declaration and also the relevant human procedures were approved by the ethical standards of Tehran University of Medical Sciences (ethic number: IR.TUMS.VCR. REC.1398.429). Also, informed written consent was signed by all study participants.

Eligibility criteria

Some participants were excluded from the study due to a history of diabetes, cancer, and CVD due to dietary changes, and only seemingly healthy people and willing to participate in the mentioned age range who were members of the health center in Tehran were included in the present study.

Demographics

The variables of this study include age, sex, marital status (single, married, divorced, dead spouse), job status (employee, housekeeper, retired, unemployed), physical activity level (low activity, moderate, vigorous), academic level (illiterate, under diploma, diploma, educated), and also smoking status (not smoking, quit smoking, low smoking) were assessed by validated questionnaires [24].

Assessment of dietary intake

We used three 24-hour recalls to assess participants' usual dietary intake. A trained interviewer was made the first 24-hour recall during a face-to-face interview [25] and the other two recalls by a phone call to the participants on random days of the week. We also included the crude or energy-adjusted macronutrient intakes and total energy intake of participants in the software. Macronutrients were considered as a percentage of total energy intake.

Identification of nutrient pattern

We used the principal component analysis (PCA) method to identify nutrient patterns. Then, we used factor analysis with the varimax procedure to identify nutrient patterns based on 37 nutrients and bioactive compounds. The Bartlett test with a p value less than 0.05 was significant, the Kaiser-Meyer-Olkin test (KMO) more than 0.6, and anti-image more than 0.5, indicated that the correlation among the variables was significantly strong for factor analysis. Also, the factors were preserved for eigenvalues on the Scree test [26], in the following nutrient and loading factors arranged into three patterns based on the type of nutrient patterns. In this study, factors with eigenvalues > 3 were retained because the following interpretable dietary patterns are obtained through this cut-off. In addition, the eigenvalues ≤ 3 could not explain adequate amounts of the overall variation. Estimating the factor score for each nutrient pattern by summing up intakes of nutrients weighted by their factor loadings [26]. Each participant received a factor score for each identified pattern [27]. Since in the nutritional epidemiology simple linear dose-response associations, are not easily found [27], we categorized the subjects based on quintiles of nutrient pattern scores.

Physical activity

The physical activity of the participants was evaluated using the International Physical Activity Questionnaire (IPAQ), which is an interview-administered instrument. Based on the criteria, data were obtained regarding walking and moderate to severe activity, in the preceding week. Also, based on the time of training and its frequency, the physical activity score was recorded. In the current study, we applied the short form of the IPAQ (the "last 7 7-day recall" version of the IPAQ-SF), which records three intensity levels of activity based on the metabolic equivalents (METs). Finally, METs were ordered as follow:

Low (< 600 MET-minutes/week), moderate (600–3,000 MET-minutes/week), and severe (> 3,000 MET-minutes/week).

Assessment of anthropometric measures

We assessed the anthropometric data including weight, height, body mass index (BMI), waist to hip ratio (WHR), and waist circumference (WC). Weight measurement by a digital scale with a sensitivity of 0.1 kg (seca 808; seca GmbH & Co. KG, Hamburg, Germany), and the subjects with minimal clothing and without shoes. Standing height measurement while shoulders were in a normal position, without shoes by wall stadiometer with a sensitivity of 0.1 cm (Seca GmbH & Co. KG). BMI was calculated and expressed in kg/ m². Finally, the participants were divided into 3 categories based on BMI: natural weight (24.9 kg/ m²), overweight (29.25.9 kg/ m²), and obese (≥ 30 kg/ m²). Since the WC is a tool for assessing abdominal obesity. WC measurement during exhalation was the midpoint between the last palpable rib and the iliac crest using the tape. So, participants based on WC were classified into 3 groups as follows: normal (< 80 cm for women, < 94 cm for men) abdominal overweight (80–88 cm for women, 94–102 cm for men) and abdominal obesity (> 88 cm for women and > 102 cm for men). All measurements were assessed by the same trained technician to reduce subjective possible errors.

Assessment of blood pressure

The participants rested sitting for 5 to 10 minutes before blood pressure measurements. Also, to assess people's blood pressure from a digital pressure gauge (Bc 08; Beurer GmbH, Ulm, Germany) was used. The systolic blood pressure (SBP) was defined as the first sound was heard, and the diastolic blood pressure (DBP) was determined as the disappearance of the sound. If SBP ≥ 140 and DBP ≥ 90, people with a history of hypertension and those who take blood pressure-lowering medications, they are considered as a patient with high blood pressure.

Statistical method

Comparing demographic variables across quintiles of nutrient pattern scores using χ^2 tests were done. Dietary intake, obesity indicators were compared in the nutrient pattern categories using analysis of variance (ANOVA) test and Tukey's honestly significant difference post hoc test and reported by mean ± standard deviation (SD) values. Then logistic regression was used to determine potential relation between nutrient pattern with general obesity. In the first model, we controlled for age and total energy intake. Further adjustment was made for current smoking, job status, education level, and physical activity in the second model. In the current study, all analyses were performed on both sexes. Also, the quintile of the nutrient pattern scores was considered as the reference category. Participant's clinical and demographic characteristics based on obesity status were compared according to people classification into two groups of healthy and obese people. For this aim, we applied the independent sample t-test and χ^2 test. All statistical analyses were performed with SPSS version 24.0 and Statistical significance was defined as p ≤ 0.05.

RESULTS

General characteristics of participants are shown in **Table 1**. Compared to healthy subjects, obese subjects were older, had a greater DBP, SBP, BMI, weight, WC (p < 0.001 for all comparisons), and WHR (p = 0.002). **Table 2** shows the principal factor loading of nutrients intake. Positive and negative loading indicated strong and weak correlations between nutrient groups and nutrient patterns respectively. Greater adherence to the first nutrient pattern was associated with a higher intake of vitamins B_1, B_2, B_6, B_5, B_3, B_{12}, SFAs, zinc, iron, and protein. The second nutrient pattern was rich in monounsaturated fatty acids

Table 1. Clinical and demographical characteristics of participants based on obesity status

Characteristics	Healthy subjects	Obese subjects	p value
Gender (%)			0.730
Men	20	18.3	
Women	80	81.7	
Age (yr)	41.37 ± 11.22	45.00 ± 9.77	< 0.001
Weight (kg)	66.95 ± 9.65	87.09 ± 13.48	< 0.001
BMI (kg/m²)	25.08 ± 2.85	33.82 ± 6.49	< 0.001
WHR	0.85 ± 0.08	0.88 ± 0.18	0.002
WC (cm)	85.36 ± 10.12	100.00 ± 10.45	< 0.001
SBP (mmHg)	114.34 ± 19.51	122.78 ± 21.45	< 0.001
DBP (mmHg)	77.36 ± 12.14	80.99 ± 16.10	0.001

Values are presented as mean ± standard deviation. The p value obtained from independent sample t-test and χ^2 test.
BMI, body mass index; WHR, waist to hip ratio; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 2. Principal factor loading of nutrients intake

Nutrient	Pattern 1	Pattern 2	Pattern 3
Vitamin B1	0.823		
Vitamin B2	0.809		
Vitamin B6	0.802		
Vitamin B5	0.799		
Zinc	0.725	0.487	
Vitamin B3	0.612		
Vitamin B12	0.575		
Iron	0.528		
SFA	0.479	0.462	
Manganese			
Selenium			
Molybdenum			
Vitamin E		0.790	
α-tocopherol		0.760	
Oleic acids		0.695	
PUFA		0.584	
β-carotene		0.543	
Linolenic acids		0.506	
MUFA		0.486	
Total fat		0.460	
Vitamin A			
Biotin			
Vitamin D			
Caffeine			
Linoleic acids			
Chromium			
Potassium			0.862
Magnesium			0.850
Phosphorus			0.822
Calcium			0.713
Protein	0.484		0.602
Carbohydrate			0.564
Vitamin C			0.501
Folate			0.470
Sodium			
Vitamin K			
Cholesterol			
Percent of variance explained	25.045	10.198	7.360

Factor loadings of < 0.2 have been removed to simplify the table. Extraction method: principal component analysis; Rotation method (converged in 7 itera): Varimax with Kaiser Normalization.
SFA, saturated fatty acid; PUFA, polyunsaturated fatty acids; MUFA, monounsaturated fatty acids.

(MUFAs), polyunsaturated fatty acids (PUFAs), zinc, SFAs, vitamin E, α-tocopherol, oleic acids, β-carotene, α-tocopherol, linolenic acids, and total fat. The third nutrient pattern was characterized by the high intake of vitamin C, phosphorus, calcium, potassium, magnesium, protein, carbohydrate, and folate. **Table 3** shows the nutrient intake across quintiles of nutrient patterns. In the first nutrient pattern, participants in the fifth quintile had a higher consumption of vitamins B1, B2, molybdenum, B6, zinc, iron, B5, Niacin, B12, potassium, magnesium, phosphorus, total fat, carbohydrate, PUFA, SFA, vitamin E, calcium, sodium, cholesterol, protein and lower intake of vitamin K, caffeine, and β-carotene. In the second one individuals in the first quintile had less intake of zinc, SFAs, vitamin E, PUFA, β-carotene, linolenic acid, α-tocopherol, oleic acid, MUFA compared to the fifth quintile. Additionally, in the third nutrient pattern, the participants in the fifth quintile had a higher intake of potassium, calcium, protein, magnesium, phosphorous, carbohydrate, vitamin C, and folate compared to other quintiles. Components of obesity across based on gender and across quintiles of nutrient patterns are shown in **Table 4**. There was a significant difference between quintiles in the first nutrient pattern in women for SBP and DBP (p = 0.029), and there was a significant difference between quintile 2 and quintile 5 groups (p = 0.025). Quintile 3 individuals had higher DBP in the first nutrient pattern than quintile 2 participants (p = 0.023). In the third nutrient pattern, we observed a significant association for SBP in women (p = 0.02). Quintile 2 individuals had a higher SBP than quintile 1 individuals in the third nutrient pattern (p = 0.04). No other significant differences were observed in terms of other variables across categories of nutrient patterns. We analyzed the association between obesity, according to quintiles of nutrient patterns for both genders, by using an unadjusted, partially, and fully adjusted model. For every 3 nutrient patterns, we did not consider the effect of the nutrient pattern for men and women, even after adjustment for confounders in the second and third nutrient patterns. A significant difference between quintiles was reported in the first nutrient pattern in women (Model 1, p = 0.01). The outcome was similar after adjustment for potential confounders (Model 2, p = 0.01 and Model 3, p = 0007) (**Table 5**). Characteristics of research participants through quintiles of major nutrient pattern scores are shown in **Supplementary Table 1**. There were significant relations for gender between quintiles in the first (p <0.006) and second nutrient pattern (p < 0.01), but not in the third (p < 0.09). In addition, a significant association for job status between quintiles in the first nutrient pattern (p < 0.05), but not in the second and third was reached. There was no significant relation for physical activity, education, marriage, and smoking between quintiles in the three nutrient patterns.

DISCUSSION

This study revealed the first nutrient pattern was positively related to blood pressure in women. Furthermore, adherence to the first nutrient pattern was associated with greater odds of obesity even after adjustment for covariates. Additionally, we detected a significant change between quintiles in the first nutrient pattern in women for obesity, SBP, and DBP. Furthermore, a significant association was also seen for SBP in women in the third nutrient pattern.

Some studies examined the association between nutrient patterns and obesity. For instance, high intake of whole grains, legumes, and fruit and less intake of refined cereals, fried foods, desserts, and fruit juice was associated with a lower risk of overweight and obesity compared with those consuming other nutrient pattern groups among vegetarians [28]. A Chinese study underlined that the traditional south pattern- rice with chicken and vegetables- was related to a reduced risk of general and abdominal obesity [19].

Table 3. Nutrient intakes across quintiles of nutrient patterns' scores

Variables	First nutrient pattern				Second nutrient pattern				Third nutrient pattern			
	Q1	Q3	Q5	p	Q1	Q3	Q5	p	Q1	Q3	Q5	p
Vitamin B1 (mg/day)	1.34 ± 0.31	1.44 ± 0.27	2.55 ± 7.82	0.010	1.68 ± 0.98	1.55 ± 0.44	2.15 ± 7.85	0.350	1.79 ± 7.81	1.55 ± 0.43	1.89 ± 0.98	0.810
Vitamin B2 (mg/day)	1.11 ± 0.26	1.22 ± 0.22	2.21 ± 7.75	0.020	1.39 ± 0.44	1.29 ± 0.37	1.85 ± 7.78	0.460	1.56 ± 7.79	1.25 ± 0.20	1.68 ± 0.48	0.600
Vitamin B6 (mg/day)	1.45 ± 0.64	1.10 ± 0.35	2.57 ± 9.51	0.005	1.80 ± 5.68	1.13 ± 0.45	2.21 ± 7.67	0.040	1.48 ± 7.72	1.18 ± 0.28	2.28 ± 5.65	0.070
Vitamin B5 (mg/day)	3.92 ± 1.08	3.44 ± 0.72	6.27 ± 11.16	< 0.001	4.82 ± 8.02	3.53 ± 1.10	5.09 ± 8.03	0.004	3.41 ± 8.07	3.85 ± 1.94	5.13 ± 3.32	0.030
Zinc (mg/day)	6.71 ± 2.01	6.05 ± 1.37	8.80 ± 7.95	< 0.001	6.57 ± 1.87	6.39 ± 1.86	8.34 ± 7.92	< 0.001	5.51 ± 7.97	6.49 ± 1.02	8.69 ± 2.02	< 0.001
Vitamin B3 (mg/day)	15.16 ± 4.77	15.56 ± 2.88	24.84 ± 20.77	< 0.001	20.16 ± 19.86	16.92 ± 32,275.31	18.23 ± 9.25	0.002	13.98 ± 8.72	17.35 ± 5.97	21.40 ± 12.90	< 0.001
Vitamin B12 (µg/day)	1.94 ± 1.24	2.03 ± 0.92	4.59 ± 13.37	< 0.001	2.29 ± 1.70	2.31 ± 1.27	3.81 ± 13.40	0.070	3.21 ± 13.39	2.25 ± 1.19	2.94 ± 2.24	0.360
Iron (mg/day)	11.52 ± 3.29	13.76 ± 4.60	23.90 ± 35.31	< 0.001	22.59 ± 34.81	14.77 ± 5.27	13.40 ± 9.32	< 0.001	11.25 ± 9.13	14.27 ± 4.96	24.34 ± 34.44	< 0.001
SFA (g/day)	15.64 ± 4.73	14.25 ± 4.20	19.62 ± 9.22	< 0.001	13.27 ± 4.11	15.67 ± 4.82	19.01 ± 8.77	< 0.001	12.75 ± 8.36	15.68 ± 4.48	19.01 ± 5.36	< 0.001
Manganese (mg/day)	3.83 ± 1.13	3.02 ± 0.84	49.40 ± 436.20	0.110	48.48 ± 436.23	3.20 ± 0.92	4.65 ± 7.95	0.120	3.23 ± 8.07	3.41 ± 3.11	4.36 ± 1.20	0.130
Selenium (mg/day)	0.14 ± 0.85	0.19 ± 1.57	73.80 ± 682.82	0.090	73.18 ± 682.85	0.07 ± 0.02	0.87 ± 7.88	0.100	0.74 ± 21,467.73	0.07 ± 0.03	73.19 ± 682.85	0.100
Molybdenum	25.29 ± 22.11	20.75 ± 17.02	35.64 ± 55.81	< 0.001	27.70 ± 53.05	22.89 ± 22.99	29.63 ± 26.99	< 0.001	15.36 ± 16.89	30.17 ± 53.64	31.82 ± 28.12	< 0.001
Vitamin E (mg/day)	14.17 ± 9.00	4.08 ± 3.69	4.55 ± 8.37	< 0.001	2.50 ± 91.58	4.14 ± 2.83	16.76 ± 10.49	< 0.001	4.29 ± 8.5	6.06 ± 5.69	9.50 ± 8.97	< 0.001
α-tocopherol (mg/day)	12.77 ± 6.89	6.31 ± 3.38	8.21 ± 8.92	< 0.001	4.72 ± 1.75	6.51 ± 2.74	16.19 ± 9.18	< 0.001	5.82 ± 8.12	7.55 ± 4.80	10.84 ± 6.30	< 0.001
Oleic acids (g/day)	20.47 ± 18.82	11.07 ± 5.11	13.16 ± 8.99	< 0.001	8.50 ± 3.15	11.63 ± 4.16	24.36 ± 19.13	< 0.001	11.29 ± 19.39	12.95 ± 5.96	16.67 ± 8.55	< 0.001
PUFA (g/day)	17.94 ± 5.99	16.35 ± 4.88	19.60 ± 9.85	< 0.001	12.87 ± 3.91	17.16 ± 3.76	22.64 ± 10.16	< 0.001	14.78 ± 9.35	16.87 ± 4.88	19.72 ± 6.36	< 0.001
β-carotene (µg/day)	1,355.09 ± 894.34	251.80 ± 232.10	212.61 ± 220.72	< 0.001	216.47 ± 180.47	305.49 ± 366.03	1,274.45 ± 942.90	< 0.001	222.48 ± 239.22	473.80 ± 574.45	758.69 ± 864.12	< 0.001
Linolenic acids (g/day)	18.91 ± 18.27	9.64 ± 8.10	13.94 ± 12.22	< 0.001	7.71 ± 6.26	10.98 ± 8.04	23.34 ± 19.07	< 0.001	7.60 ± 11.21	12.48 ± 13.75	17.46 ± 12.24	< 0.001
MUFA (g/day)	24.87 ± 38.99	15.74 ± 14.01	20.14 ± 10.00	< 0.001	12.58 ± 4.22	16.21 ± 5.43	30.59 ± 40.62	< 0.001	16.31 ± 39.65	17.10 ± 6.13	21.88 ± 8.05	0.005
Total fat (g/day)	64.10 ± 34.60	51.64 ± 13.34	66.92 ± 19.09	< 0.001	45.98 ± 14.00	55.96 ± 13.05	76.45 ± 33.09	< 0.001	45.21 ± 13.57	56.36 ± 13.28	71.45 ± 34.14	< 0.001
Vitamin A (µg/day)	1,140.12 ± 686.72	521.81 ± 252.35	555.27 ± 311.06	< 0.001	523.47 ± 269.10	601.16 ± 362.15	1,075.70 ± 698.61	< 0.001	453.26 ± 377.31	687.68 ± 427.93	964.86 ± 603.33	< 0.001
Biotin (µg/day)	18.34 ± 9.86	11.47 ± 5.09	16.64 ± 47.19	0.009	11.36 ± 5.99	11.61 ± 5.09	23.68 ± 47.21	< 0.001	13.56 ± 47.03	12.62 ± 5.53	18.63 ± 11.54	0.030
Vitamin D (µg/day)	6.26 ± 21.34	1.40 ± 5.89	5.57 ± 52.78	0.100	0.91 ± 1.42	0.75 ± 0.76	11.49 ± 56.68	< 0.001	5.12 ± 52.8	1.54 ± 8.15	5.87 ± 19.03	0.220
Caffeine (g/day)	135.13 ± 48.57	116.88 ± 38.01	108.56 ± 38.72	< 0.001	102.18 ± 37.39	118.44 ± 35.61	138.12 ± 48.36	< 0.001	109.62 ± 53.38	115.54 ± 36.46	126.48 ± 36.23	0.007
Linoleic acids (g/day)	9.80 ± 54.03	5.87 ± 8.02	4.76 ± 10.22	0.380	3.87 ± 5.60	5.12 ± 7.27	11.14 ± 54.72	0.080	11.85 ± 53.75	6.32 ± 10.24	3.26 ± 7.91	0.020
Chromium (mg/day)	14.01 ± 181.40	0.45 ± 5.48	0.70 ± 7.71	0.420	0.09 ± 0.66	0.03 ± 0.07	15.03 ± 181.57	0.330	14.58 ± 181.52	0.10 ± 0.66	0.05 ± 0.03	0.370
Potassium (mg/day)	2,486.77 ± 628.00	2,327.20 ± 495.01	2,861.71 ± 1,283.83	< 0.001	2,689.72 ± 1,161.55	2,351.53 ± 860.33	2,685.70 ± 594.13	< 0.001	1,802.07 ± 352.03	2,383.33 ± 306.16	3,379.88 ± 1,162.93	< 0.001
Magnesium (mg/day)	239.68 ± 69.61	205.69 ± 53.79	267.61 ± 108.58	< 0.001	244.45 ± 96.55	210.45 ± 75.48	267.64 ± 63.63	< 0.001	157.66 ± 34.63	211.15 ± 29.05	328.50 ± 91.40	< 0.001
Phosphorus (mg/day)	915.65 ± 283.23	781.82 ± 179.34	1,008.41 ± 261.28	< 0.001	849.25 ± 225.33	806.59 ± 216.63	1,040.19 ± 270.85	< 0.001	602.18 ± 124.63	829.60 ± 115.13	1,154.44 ± 264.85	< 0.001
Calcium (mg/day)	589.46 ± 589.46	609.69 ± 174.79	770.76 ± 248.55	< 0.001	755.22 ± 253.90	612.07 ± 182.47	632.89 ± 218.39	< 0.001	441.17 ± 122.54	618.41 ± 124.11	876.92 ± 239.27	< 0.001
Protein (g/day)	54.35 ± 13.40	55.29 ± 8.53	74.44 ± 15.81	< 0.001	61.65 ± 13.51	57.73 ± 13.69	62.24 ± 17.53	< 0.001	46.96 ± 14.63	58.31 ± 8.10	73.81 ± 14.06	< 0.001
Carbohydrate (g/day)	228.94 ± 43.92	225.12 ± 35.55	277.53 ± 81.59	< 0.001	250.92 ± 80.06	236.18 ± 56.50	245.36 ± 41.32	< 0.001	191.61 ± 37.75	238.91 ± 36.73	283.64 ± 74.51	< 0.001
Vitamin C (µg/day)	97.63 ± 41.46	95.37 ± 43.10	101.32 ± 57.48	0.490	100.98 ± 55.33	93.99 ± 51.63	103.70 ± 44.39	0.020	70.60 ± 35.44	97.44 ± 36.51	127.29 ± 59.47	< 0.001
Folate (µg/day)	306.72 ± 124.37	214.31 ± 58.03	225.43 ± 73.44	< 0.001	206.87 ± 66.46	217.10 ± 61.07	343.70 ± 250.20	< 0.001	175.98 ± 247.23	228.44 ± 55.65	336.64 ± 256.22	< 0.001
Sodium (mg/day)	1,988.96 ± 851.95	2,009.07 ± 500.20	3,247.57 ± 6,210.34	< 0.001	2,682.32 ± 6,232.82	2,372.99 ± 1,730.75	2,273.02 ± 901.49	0.280	1,742.52 ± 559.54	2,162.18 ± 652.44	3,321.40 ± 6,386.51	< 0.001
Vitamin K (µg/day)	149.37 ± 148.30	75.91 ± 47.03	64.81 ± 42.40	< 0.001	61.04 ± 36.83	73.87 ± 39.09	150.67 ± 134.83	< 0.001	62.89 ± 37.29	84.49 ± 53.18	136.75 ± 158.07	< 0.001
Cholesterol (mg/day)	205.82 ± 101.08	202.05 ± 103.01	244.91 ± 119.14	< 0.001	188.39 ± 107.13	209.63 ± 118.90	233.26 ± 104.41	< 0.001	175.28 ± 94.32	204.84 ± 97.05	251.10 ± 122.82	< 0.001

Data are presented as mean ± standard deviation. The p values obtained from analysis of variance test.
SFA, saturated fatty acid; PUFA, polyunsaturated fatty acids; MUFA, monounsaturated fatty acids.

Table 4. Components of obesity across quintiles of nutrient patterns' scores

Variables	First nutrient pattern				Second nutrient pattern				Third nutrient pattern			
	Q1	Q3	Q5	p	Q1	Q3	Q5	P	Q1	Q3	Q5	p
Men												
Age (yr)	42.45 ± 13.77	44.39 ± 10.26	41.80 ± 11.34	0.890	44.23 ± 11.05	40.13 ± 10.22	45.04 ± 12.13	0.190	40.71 ± 14.09	42.74 ± 8.47	43.61 ± 10.47	0.830
Weight (kg)	79.20 ± 11.12	80.44 ± 18.78	84.83 ± 20.77	0.640	82.91 ± 16.02	86.25 ± 21.42	77.45 ± 14.93	0.280	77.90 ± 16.15	79.51 ± 15.99	84.90 ± 18.77	0.480
BMI (kg/m²)	26.35 ± 3.20	26.99 ± 7.19	27.70 ± 5.35	0.880	27.82 ± 4.12	27.86 ± 5.86	26.56 ± 6.73	0.750	26.18 ± 4.98	27.03 ± 4.25	28.08 ± 6.20	0.630
WHR	0.90 ± 0.06	0.91 ± 0.09	0.91 ± 0.09	0.900	0.90 ± 0.10	0.91 ± 0.07	0.89 ± 0.06	0.140	0.89 ± 0.07	0.92 ± 0.11	0.91 ± 0.08	0.800
WC (cm)	89.55 ± 8.79	91.64 ± 15.45	93.97 ± 16.77	0.590	125.87 ± 21.09	118.43 ± 21.86	120.58 ± 29.70	0.720	87.03 ± 12.71	90.29 ± 15.17	94.68 ± 16.53	0.170
SBP (mmHg)	124.25 ± 17.87	120.46 ± 30.43	127.56 ± 16.33	0.220	125.87 ± 21.09	118.43 ± 21.86	120.95 ± 29.70	0.610	125.03 ± 24.83	120.82 ± 24.37	122.59 ± 24.36	0.930
DBP (mmHg)	75.75 ± 17.39	78.57 ± 22.00	83.86 ± 12.05	0.350	82.87 ± 16.84	79.00 ± 15.83	76.33 ± 17.96	0.550	83.00 ± 18.55	80.17 ± 14.79	79.97 ± 22.14	0.880
Women												
Age (yr)	42.26 ± 10.80	41.21 ± 11.57	41.28 ± 11.00	0.200	42.24 ± 10.64	42.72 ± 10.67	41.68 ± 10.75	0.940	42.52 ± 11.24	44.23 ± 11.28	41.66 ± 10.99	0.170
Weight (kg)	70.53 ± 12.03	68.92 ± 11.56	68.88 ± 11.95	0.610	70.73 ± 11.38	70.69 ± 12.24	69.54 ± 12.32	0.300	69.77 ± 11.06	69.16 ± 11.63	69.10 ± 11.64	0.770
BMI (kg/m²)	27.64 ± 4.86	27.48 ± 8.78	26.64 ± 4.54	0.650	27.63 ± 5.55	27.74 ± 4.58	26.97 ± 4.67	0.340	28.04 ± 9.02	27.16 ± 4.37	26.68 ± 4.32	0.360
WHR	0.83 ± 0.06	0.85 ± 0.07	0.86 ± 0.23	0.360	0.86 ± 0.23	0.85 ± 0.07	0.84 ± 0.07	0.520	0.83 ± 0.09	0.85 ± 0.07	0.86 ± 0.23	0.200
WC (cm)	88.12 ± 11.29	88.44 ± 10.59	86.87 ± 12.22	0.440	88.68 ± 11.48	90.00 ± 10.82	87.73 ± 11.70	0.150	87.81 ± 11.19	88.00 ± 11.24	87.88 ± 11.02	0.730
SBP (mmHg)	118.10 ± 22.09[a]	114.45 ± 19.73[a]	112.63 ± 19.72[b]	0.020	113.52 ± 20.58	116.33 ± 18.16	117.98 ± 18.24	0.060	110.58 ± 24.45[b]	117.02 ± 16.51[a]	116.71 ± 21.43[a]	0.020
DBP (mmHg)	79.05 ± 13.69[a]	79.58 ± 14.36[b]	77.70 ± 9.60[a]	0.020	76.28 ± 12.21	78.66 ± 11.37	78.51 ± 12.74	0.300	77.14 ± 17.87	78.68 ± 12.11	78.80 ± 11.49	0.700

Data are presented as mean ± standard deviation. The p values obtained from analysis of variance test.
BMI, body mass index; WHR, waist to hip ratio; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure.
[a,b]Tukey post hoc test: means with the same letter indicate no significant difference. Any difference between 2 means carrying different letters is significant at 5%.

Table 5. General obesity according to quintiles (Q) of nutrient patterns, stratified by gender

Variables	First nutrient pattern				Second nutrient pattern				Third nutrient pattern			
	Q1	Q3	Q5	p-trend	Q1	Q3	Q5	p-trend	Q1	Q3	Q5	p-trend
Men												
Model 1	1	2.68 (0.62–11.57)	1.57 (0.38–6.46)	0.810	1	0.95 (0.37–2.43)	0.48 (0.14–1.68)	0.250	1	0.77 (0.23–2.56)	0.77 (0.25–2.37)	0.450
Model 2	1	2.72 (0.62–11.84)	1.64 (0.36–7.52)	0.960	1	0.97 (0.37–2.51)	0.50 (0.14–1.75)	0.280	1	0.74 (0.19–2.87)	0.70 (0.13–3.67)	0.590
Model 3	1	2.48 (0.56–11.02)	1.45 (0.30–6.89)	0.840	1	0.98 (0.37–2.58)	0.52 (0.13–2.09)	0.360	1	0.59 (0.14–2.41)	0.56 (0.10–3.05)	0.500
Women												
Model 1	1	0.44 (0.25–0.75)	0.52 (0.30–0.91)	0.010	1	0.93 (0.54–1.62)	0.89 (0.52–1.53)	0.810	1	0.74 (0.43–1.29)	0.93 (0.54–1.61)	0.610
Model 2	1	0.45 (0.25–0.79)	0.51 (0.28–0.91)	0.010	1	0.92 (0.53–1.60)	0.93 (0.53–1.64)	0.720	1	0.66 (0.36–1.22)	0.90 (0.43–1.86)	0.600
Model 3	1	0.45 (0.25–0.80)	0.50 (0.27–0.90)	0.007	1	0.91 (0.52–1.61)	0.95 (0.53–1.68)	0.730	1	0.63 (0.34–1.17)	0.86 (0.41–1.79)	0.490

Values are presented as odds ratio (95% confidence interval). Model 1: unadjusted, Model 2: age, total energy intake, Model 2: additionally adjusted for current smoking, job status, education level and physical activity.

In the current study, the first nutrient pattern loaded largely on vitamins (B1, B2, B6, B5, B3, B12) and zinc. The association between low levels of B vitamins such as B1, B2, and B6 and obesity was demonstrated in some studies [30-32]. Low levels of B1, B3, and B6 are associated with metabolic dysfunction such as obesity [30-32]. Patients with obesity may have a higher amount of body thiamine reservation in cells that result in lower plasma thiamine levels [31]. Elevated total body water in obese individuals can possibly lead to dilution of the extracellular compartment and reducing the plasma levels of vitamin [30]. However, in a clinical trial performed by Dollerup et al [33], supplementation with 1,000 mg nicotinamide riboside twice a day for 12-weeks had no significant effect on the body composition measures. In relation to zinc and obesity, supplementation with 10 mg amino acid chelated zinc along with vitamins and minerals versus just vitamins and minerals except for zinc for 3 months, zinc supplement improved indices of body composition including triceps skinfold and mid-arm circumference in children [34]. Moreover, abdominal obesity and high body fat percentage were positively linked to serum concentrations of zinc in men. However, this association was not observed in women [35]. On the contrary, plasma zinc levels were inversely associated with BMI in a cross-sectional study [36]. In line with our research, some studies have proposed that thiamin [9] and niacin [37] are positively associated with obesity. Because of the appetite-stimulating effect of prolonged intake of B vitamins which can lead to extra weight gain [38].

Our second nutrient pattern (mainly loaded by PUFAs, oleic acid, vitamin E, and α-tocopherol) is positively related to body weight and height. In contrast to our result, Barzegar-Amini et al. [39] showed that serum vitamin E is inversely associated with WC, and hip circumference. Nonetheless, the body weight reduction was not significant [39]. Furthermore, tocotrienol is supposed to suppress adipocytes differentiation, thus may play a role to prevent obesity [40]. There is evidence that diet can change epigenetic marks [41,42], few studies have been performed concerned with the effect of vitamin E on epigenetic mechanisms, in mice, tocopherols could reduce DNA methylation in diverse genes [43,44]. Vitamin E has been linked to alterations in the DNA methylation profile and that the decrease or increase in methylation levels is gene-specific [45]. The omega-6/omega-3 PUFAs ratio is crucial. A diet including usual meat rather than fish can cause an imbalance in that ratio. The fat reservation caused by dietary omega-6 PUFAs may have more progression compared to long-chain omega-3 or SFAs when consumed along with a roughly high carbohydrate diet [46]. Omega-6 PUFAs may stimulate fat mass build-up containing prevention of rising in fatty acid oxidation, basal metabolic rate increase, the elevation of protein and muscle synthesis, and progression of fat-storing prostaglandins, endocannabinoids, and augmented hunger [47]. The thermic effect of the MUFA-rich meal was also high compared to the SFA-rich meal in subjects with a high WC [48]. Substituting a high MUFA diet for a diet rich in SFA significantly reduced body weight and fat mass in overweight and obese men [49].

The third nutrient pattern largely comprises protein, potassium, phosphorus, magnesium, and calcium. It is expected that this nutrient pattern is somehow likely the Mediterranean diet. This diet mainly includes a rich amount of fruits and vegetables which are a good source of nutrients mentioned in our third pattern. Finding from a cohort study indicated that adherence to the Mediterranean diet was associated with a lower risk of obesity up to 29% in men [50].

A high-protein low-carbohydrate diet has been observed to be more effective than other diets concerning fat loss, due to sparing lean body mass [51]. However, a systematic review of clinical trials for at least 6 months follow up revealed that no significant effect of high-protein low-carbohydrate diet at 12-month duration on weight loss. Also, this study observed no significant differences in blood pressure [52]. Many mechanisms have been suggested for a high protein diet, enhancement in weight loss induced by increasing in the protein content of the diet could be due to satiety induction, and increasing energy expenditure [53]. In addition, the elevated ratio of protein to carbohydrate can trigger to increase in the food thermic effect [54]. In a systematic review of a clinical trial of 6 months period or more [52], significant weight loss was concluded for high-protein low-carbohydrate diets at 6-month but not at 12-month of intervention.

To demonstrate the strengths and limitations of the present study, the use of three 24-hours recall to collect dietary data from our study population could be mentioned since the three 24-hours recall has been shown to be a suitable tool for assessing macronutrient and micronutrient intake. Although the sample size was small, it was good enough based on statistical calculations. We must highlight that some limitations are unavoidable. For instance, the effects of how foods are cooked on the bioavailability of the nutrients were not possible to measure, however, we tried to control for possible potential confounders. Moreover, as the study is cross-sectional in design, causal relationships cannot be recognized. Supplement intake and menopause status in women are also considered as the limitations of the study. More research about nutrient patterns in the isocaloric clinical trials seems to be helpful to develop the data on the Iranian habitual diet to establish nutritional recommendations for preventing obesity in the community.

CONCLUSION

In conclusion, our study showed three major nutrient patterns that indicated the principle factor loading of nutrient intake. We detected a significant difference between quintiles in the first nutrient pattern in women for obesity, SBP, and DBP. Furthermore, we found a significant association for SBP in women in our third nutrient pattern. More clinical trials appear to be useful for more investigations on the Iranian habitual diet in order to set up required nutritional recommendations for the general population.

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SUPPLEMENTARY MATERIAL

Supplementary Table 1
Characteristics of study participants across quintiles of major nutrient pattern scores

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