Eur J Nutr (2016) 55:505–518
DOI 10.1007/s00394-015-0867-4

ORIGINAL CONTRIBUTION

Nutrient patterns and their relation to general and abdominal obesity in Iranian adults: findings from the SEPAHAN study

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Received: 17 July 2014 / Accepted: 23 February 2015 / Published online: 3 March 2015

Abstract
Background Few studies have linked major dietary nutrient patterns to chronic diseases. Despite the growing evidence of associations between dietary patterns and obesity, we are aware of no study that examined the association between patterns of nutrient intake and obesity.
Objective To identify major nutrient patterns in Iranian adults and investigate their association with general and abdominal obesity.
Methods In this cross-sectional study that was conducted under the framework of the Study on the Epidemiology of Psychological Alimentary Health and Nutrition (SEPAHAN), dietary data were collected using a validated dish-based 106-item semi-quantitative food frequency questionnaire in 8691 subjects aged 18–55 years. Complete data of 6724 and 5203 adults were available for general and abdominal obesity, respectively. Data on anthropometric measures were collected through a self-administered questionnaire. General obesity was defined as body mass index ≥ 30 kg/m^2, and abdominal obesity as waist circumference > 102 cm for men and >88 cm for women. Daily intakes of 38 nutrients and bioactive compounds were calculated for each participant. Factor analysis, followed by a varimax rotation, was applied to derive major nutrient patterns.
Results Three major nutrient patterns were identified: (1) The first pattern was high in fatty acids (including saturated, monounsaturated and polyunsaturated fatty acids), cholesterol, vitamin B_{12}, vitamin E, zinc, choline, protein, pyridoxine, phosphorus and pantothenic acid; (2) the second pattern was high in thiamine, betaine, starch, folate, iron, selenium, niacin, calcium, and manganese; and (3) the third pattern was high in glucose, fructose, sucrose, vitamin C, potassium, total dietary fiber, copper and vitamin

Electronic supplementary material The online version of this article (doi:10.1007/s00394-015-0867-4) contains supplementary material, which is available to authorized users.

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K. Men in the highest quintile of the second pattern were less likely to be generally obese in the fully adjusted model [odds ratio (OR) 0.39, 95 % confidence interval (CI) 0.20–0.76]. After adjustment for potential confounders, a significant positive association was observed between the third pattern and general obesity among men (OR 1.77, 95 % CI 1.04–3.04), but not women (OR 1.18, 95 % CI 0.74–1.88). No overall association was seen between patterns of nutrient intake and abdominal obesity in both genders.

Conclusion Major nutrient patterns were significantly associated with general, but not abdominal obesity among male participants of the SEPAHAN study. Further studies in other populations, along with future prospective studies, are required to confirm these findings.

Keywords Anthropometry · Obesity · Diet · Nutrient intake · Factor analysis · Fat accumulation

Abbreviations

NP	Nutrient pattern
BMI	Body mass index
WC	Waist circumference
CVDs	Cardiovascular diseases
SEPAHAN	Study on the epidemiology of psychological alimentary health and nutrition
DS-FFQ	Dish-based Semi-quantitative Food Frequency Questionnaire
USDA	United States Department of Agriculture
SFAs	Saturated fatty acids
MUFAs	Monounsaturated fatty acids
PUFAs	Polyunsaturated fatty acids
TFAs	Trans fatty acids
NCEP	National Cholesterol Education Program
GPPAQ	General Practice Physical Activity Questionnaire
ANCOVA	Analysis of covariance
PAI	Physical activity index

Introduction

Although studying individual nutrients and foods has assisted researchers in taking important steps to identify not only deficiency, but also overconsumption-related diseases, it is becoming increasingly apparent that a combination of these dietary exposures may affect chronic diseases [1]. Dietary pattern analysis has recently emerged in nutritional epidemiology examining diet–disease relationships [2]. In this approach, statistical methods are used to combine multiple foods or nutrients to derive single-exposure variables, or dietary patterns [3]. It has been suggested that such dietary patterns may provide a better and more general insight into diet–disease relations [2] and may be more predictive of chronic disease risk than the intake of individual nutrients or foods [3]. Furthermore, effects from single nutrients or foods may be too small to be detectable, while there may be significant associations between dietary patterns and risk of obesity, diabetes, cardiovascular disease and some cancers [3].

Although food patterns can predict risk of chronic conditions, the mechanisms through which these patterns might influence the risk cannot be explained by this approach. Food patterns affect the risk of chronic diseases through nutrient intakes, and it is, most likely, a combination of nutrients, rather than an individual one, that will affect the risk [4–11]. Therefore, a pattern of nutrients may provide more information about probable underlying mechanisms. In contrast to food patterns, few studies have considered nutrient patterns in relation to chronic diseases [4–11]. The approach of nutrient patterns might provide novel insight into the possible relations between nutrients in the etiology of chronic conditions. Furthermore, nutrient pattern analysis could be used to compare nutritional status between different populations. Although foods, and the way they are prepared, may vary from one population to another due to behavioral, cultural and geographical/climate differences, this may not be the case for nutrients. Thus, unlike specific foods, nutrients are universal and consumed by people from different backgrounds and cultures [7].

The prevalence of obesity has been increasing at an alarming rate [12]. In 2008, the World Health Organization reported that worldwide obesity has doubled since 1980 [12]. Obesity is also a growing health problem in developing countries in the Middle East [13]; for instance, in Iranian adults, its prevalence has increased from 13.6 to 22.3 % from 1999 to 2007 [14]. Obesity is one of the leading preventable risks for global deaths, and considered as an important risk factor for a number of chronic diseases, including diabetes, cardiovascular diseases and certain cancers [12]. A direct association between certain nutrients, particularly dietary fat [15] and carbohydrates [16], and the risk of obesity has been reported, while consumption of dietary proteins [17] and fiber [18], or individual micronutrients, including vitamins A, B, C [19, 20] and D [21], and minerals, such as calcium [22], has been inversely related to obesity. In contrast, we are unaware of any studies examining associations between patterns of nutrient intake with obesity. There are reports of associations between nutrient patterns with other chronic diseases, including osteoporosis and some cancers [4–6, 8–11]. For instance, nutrient patterns high in antioxidants [4], or vitamins and fiber [6], may be protective against esophageal squamous cell carcinoma and breast and ovarian cancers, respectively. A higher intake of calcium, phosphorus, vitamin B_{12}, proteins, unsaturated fats and moderate alcohol has been linked to reduced wrist and hip fractures [11]. Studying the patterns of nutrient intake in association with obesity may, thus, provide insights as to which combinations of nutrients might affect obesity risk.

Therefore, the main aim of this study was to identify the major nutrient patterns in Iranian adults participating in the SEPAHAN study and to investigate associations of such patterns with general and abdominal obesity as a prevalent condition [14].

Materials and methods

Study design and population

The present cross-sectional study was performed within the framework of the Study on the Epidemiology of Psychological Alimentary Health and Nutrition (SEPAHAN), which included a large group of Iranian general adult population working in 50 different health centers across Isfahan province. Detailed information about the study design, participants and data collection methods has been published previously [23]. Detailed information on anthropometric measurements, sociodemographic characteristics and dietary intakes as well as physical activity was collected through the use of a self-administered questionnaire [23]. The questionnaire was sent to 10,087 people aged 18–55 years, and 8691 subjects returned the completed questionnaire (response rate 86.16 %). In the current study, participants with caloric intakes outside the range of 800–4200 kcal/day were excluded. We also excluded individuals with missing data (outcome and covariate variables). These exclusions resulted in a dataset of 6724 and 5203 adults with complete data for analysis on general and abdominal obesity, respectively. All participants provided written informed consent. The whole project of SEPAHAN was approved by the Bioethics Committee of Isfahan University of Medical Sciences, Isfahan, Iran [23].

Dietary assessment

Dietary data were collected using a Willett-format [24] Dish-based 106-item Semi-quantitative Food Frequency Questionnaire (DS-FFQ), which was designed and validated specifically for Iranian adults. Detailed information about the design, foods included as well as the face validity of this questionnaire has been reported elsewhere [25]. To develop the questionnaire, a comprehensive list of foods and dishes commonly consumed by Iranian adults was constructed. Then, we chose those foods that were nutrient-rich, consumed reasonably often, or contributed to between-persons variations. This process led to the selection of the remaining 106 food items in the questionnaire. The questionnaire contained five categories of foods and dishes: (1) mixed dishes (cooked or canned, 29 items); (2) carbohydrate-based foods (different types of bread, cakes, biscuits and potato, 10 items); (3) dairy products (dairies, butter and cream, 9 items); (4) fruits and vegetables (22 items); and (5) miscellaneous food items and beverages (including sweets, fast foods, nuts, desserts and beverages, 36 items). Participants were asked to report their dietary intakes of foods and mixed dishes based on nine multiple-choice frequency response categories varying from "never or less than once a month" to "12 or more times per day." The frequency response categories for the food list varied from 6 to 9 choices. For foods consumed infrequently, we omitted the high-frequency categories, while for common foods with a high consumption, the number of multiple-choice categories increased. For instance, the frequency response for tuna consumption included 6 categories, as follows: never or less than once/month, 1–3 times/month, 1 time per week, 2–4 times/week, 5–6 times/week and 1–2 times/day, and for tea consumption, the frequency response included 9 categories, as follows: never or less than 1 cup/month, 1–3 cups/month, 1–3 cups/week, 4–6 cups/week, 1 cup/day, 2–4 cups/day, 5–7 cups/day, 8–11 cups/day and ≥12 cups/day. Finally, we computed daily intakes of all food items and then converted them to grams per day using household measures [26]. Daily intakes of 38 nutrients (and bioactive substances) for each participant were calculated using the US Department of Agriculture's (USDA) national nutrient databank [27]. In the current analysis, we used protein, starch, total dietary fiber, glucose, fructose, sucrose, total saturated fatty acids (SFAs), total monounsaturated fatty acids (MUFAs), total polyunsaturated fatty acids (PUFAs), total trans fatty acids (TFAs), cholesterol, vitamin B_{12}, vitamin A, vitamin D, vitamin E, vitamin K, thiamin, riboflavin, niacin, pantothenic acid, pyridoxin, folate, vitamin C, theobromine, caffeine, choline, betaine, sodium, potassium, phosphorus, magnesium, iron, selenium, calcium, manganese, copper, zinc and fluoride, to identify nutrient patterns.

Anthropometric assessment

Data on height, weight and waist circumference (WC) were collected using a self-reported questionnaire. Body mass index (BMI) was calculated as weight in kilograms divided by the height in meters squared. Participants were classified into three categories based on their BMI: normal weight (≤24.9 kg/m^2), overweight (25.0–29.9 kg/m^2) and obese (≥30 kg/m^2). Abdominal obesity was defined based on waist circumference. Abdominal overweight and obesity were identified based on criteria proposed by Lean et al. and the National Cholesterol Education Program (NCEP), respectively [28, 29]. Participants were categorized into 3 groups: 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).

The validity of self-reported weight, height and WC was examined in a pilot study on 200 participants from the same population. In the validation study, self-reported values of anthropometric indices were compared with measured values. The correlation coefficients for self-reported weight, height and WC versus corresponding measured values were 0.95 ($P < 0.001$), 0.83 ($P < 0.001$) and 0.60 ($P < 0.001$), respectively. The correlation coefficient for computed BMI from self-reported values and the one from measured values was 0.70 ($P < 0.001$). These data indicate that the self-reported values of anthropometric measures provide a reasonable measure for these indices.

Assessment of covariates

To collect information about age, gender, marital status (single/married), education (high school diploma or below/above high school diploma), smoking status (non-smoker/former smoker/current smoker), family size (≤4/>4 members), breakfast consumption and home ownership (owner/non-owner), we used a self-administered questionnaire. Those who were consuming breakfast <4 times/week were defined as breakfast skippers. Physical activity levels of participants were assessed using the General Practice Physical Activity Questionnaire (GPPAQ), a simple, four-level physical activity index (PAI) reflecting an individual's current physical activity [30]. In the current analysis, we categorized participants as having <1 h/week or ≥1 h/week of moderate physical activity.

Statistical analysis

Nutrient intakes are presented based on actual units; however, the scales were harmonized using log transformation (natural logarithm) prior to running the factor analysis. Factor analysis with orthogonal transformation (varimax procedure) was applied to derive nutrient patterns based on the 38 nutrients and bioactive compounds. Factors were retained for further analysis based on their natural interpretation and eigenvalues on the Scree test [31]. In this study, we retained factors with eigenvalues >3 as this cutoff could result in more interpretable dietary patterns. In addition, factors with eigenvalues ≤3 did not explain sufficient amounts of overall variation. We computed the factor score for each nutrient pattern by summing up intakes of nutrients weighted by their factor loadings [31]. Each participant received a factor score for each identified pattern. As simple linear dose–response relationships are unlikely to be found in nutritional epidemiology [24], we categorized the subjects based on quintiles of nutrient pattern scores.

Continuous and categorical demographic variables were compared across quintiles of nutrient pattern scores using analysis of variance and Chi-square tests, respectively. We computed age-, gender- and energy-adjusted intakes of food groups and nutrients using analysis of covariance (ANCOVA). Comparison of dietary intakes across categories of nutrient pattern scores was done using ANCOVA with Bonferroni correction. Means of anthropometric measures across quintiles of nutrient pattern scores were calculated in different models for both genders. First, adjustments were done for age (continuous), and energy intake (continuous). In the second model, we further controlled for marital status (single/married), education (high school diploma or below/above that), family size (≤4/>4 members), smoking status (non-smoker/ex-smoker/current smoker), physical activity (<1 h/week/≥1 h/week), breakfast skipping (skippers/non-skippers) and home ownership (owner/non-owner). All these analyses were done using analysis of covariance with Bonferroni correction. To determine any association between nutrient patterns and general or abdominal obesity, we used binary logistic regression, with the adjustments as mentioned above. Again, these analyses were done for both genders. In these analyses, the first quintile of the nutrient pattern scores was considered as the reference category. To compute the overall trend of odds ratios across increasing quintiles of nutrient pattern scores, we used the quintiles of each pattern as an ordinal variable in the logistic regression models. All statistical analyses were done using the Statistical Package for Social Sciences (SPSS, version 16.0 for Windows, 2006, SPSS, Inc, Chicago, IL). P value <0.05 was considered statistically significant.

Results

The mean age of participants was 36.4 ± 8.1 years, and 59 % of them were women. The prevalence of general obesity among men and women was 9.0 and 9.6 %, respectively. Abdominal obesity was prevalent among 13.4 % of men and 34.1 % of women.

We identified three major nutrient patterns: The first pattern was high in individual fatty acids, cholesterol, vitamin B_{12}, vitamin E, zinc, choline, protein, pyridoxine, phosphorus and pantothenic acid (Supplementary Table 1). The second pattern was high in thiamine, betaine, starch, folate, iron, selenium, niacin, calcium and manganese. The third pattern was high in glucose, fructose, sucrose, vitamin C, potassium, total dietary fiber, copper and vitamin K. Altogether, these three nutrient patterns explained 73.4 % of the total variance of nutrient intakes in this population.

General characteristics of participants across quintiles of nutrient pattern scores are presented in Table 1. Within

Table 1 General characteristics of participants across quintiles of major nutrient pattern scores

	First nutrient pattern				Second nutrient pattern				Third nutrient pattern			
	Q1 ($n = 1192$)	Q3 ($n = 1209$)	Q5 ($n = 1194$)	P[b]	Q1 ($n = 1172$)	Q3 ($n = 1187$)	Q5 ($n = 1198$)	P	Q1 ($n = 1178$)	Q3 ($n = 1192$)	Q5 ($n = 1205$)	P
Age	37.3 ± 8.0[a]	36.7 ± 8.0	36.8 ± 8.4	0.01	36.8 ± 8.1	36.6 ± 8.4	36.9 ± 7.8	0.46	36.0 ± 7.8	36.6 ± 8.1	37.3 ± 8.3	<0.001
Gender (female) (%)	67	62	51	<0.001	64	62.5	52	<0.001	52	59	61	<0.001
Marital status (married) (%)	83	82	83	0.31	84	81	83	0.01	84	85	80	0.01
Education (higher than high school diploma) (%)	59	62	56	0.003	52	61	65	<0.001	54	60	66	<0.001
Family size (>4 people) (%)	10	11	11.5	0.43	11	10	11	0.49	11	9	10	0.01
Smoking status				<0.001				0.48				<0.001
Non-smoker	93	92	88		92	92	91		89	92	94	
Former smoker	4	5	6		5	4	6		6.0	4	3	
Current smoker	3	3	7		3.5	4	4		5	4	3	
Physically active (≥1 h/week) (%)	31	34	36	0.13	34	34	32	0.19	30	33	41	<0.001
Breakfast skipping (≥4 times/week) (%)	24	22	23	0.62	26	25	19	<0.001	32	21	17	<0.001
Home ownership (non-owner) (%)	32	31	30	0.49	31.5	30	32	0.31	39	31	27	<0.001

[a] Mean ± standard deviation (SD)

[b] Obtained from ANOVA or Chi-square test, where appropriate

Table 2 Age, gender and energy-standardized dietary and nutrient intakes across quintiles of nutrient patterns' scores

	First nutrient pattern				Second nutrient pattern				Third nutrient pattern			
	Q1	Q3	Q5	P[c]	Q1	Q3	Q5	P	Q1	Q3	Q5	P
Food groups (g/day)												
Fruits	405.7 ± 6.4[a]	290.4 ± 5.6	155.2 ± 6.7	<0.001	334.0 ± 6.6	293.5 ± 5.8	203.9 ± 6.5	<0.001	86.9 ± 4.0	241.4 ± 3.8	584.5 ± 4.0	<0.001
Vegetables	178.2 ± 3.5	202.9 ± 3.1	238.4 ± 3.7	<0.001	240.2 ± 3.5	215.6 ± 3.1	153.4 ± 3.5	<0.001	135.3 ± 2.9	200.3 ± 2.9	290.3 ± 2.9	<0.001
Dairy	237.1 ± 8.2	341.0 ± 7.2	449.4 ± 8.6	<0.001	377.3 ± 8.4	370.6 ± 7.4	280.6 ± 8.3	<0.001	295.9 ± 7.6	349.9 ± 7.4	387.7 ± 7.6	<0.001
Red meat	42.2 ± 1.0	70.1 ± 0.9	117.7 ± 1.1	<0.001	87.8 ± 1.1	81.3 ± 1.0	44.1 ± 1.1	<0.001	78.2 ± 1.1	75.5 ± 1.0	66.7 ± 1.1	<0.001
Processed meat	1.8 ± 0.3	5.3 ± 0.3	13.8 ± 0.3	<0.001	8.4 ± 0.3	7.8 ± 0.3	2.2 ± 0.3	<0.001	10.4 ± 0.3	6.1 ± 0.3	3.3 ± 0.3	<0.001
White meat	41.8 ± 1.4	60.8 ± 1.2	99.6 ± 1.4	<0.001	76.1 ± 1.4	73.2 ± 1.2	38.5 ± 1.4	<0.001	67.0 ± 1.3	66.8 ± 1.3	63.1 ± 1.3	<0.001
Legumes and nuts	49.7 ± 1.2	60.7 ± 1.1	85.6 ± 1.3	<0.001	64.9 ± 1.3	71.7 ± 1.1	48.6 ± 1.2	<0.001	60.4 ± 1.2	64.7 ± 1.1	67.2 ± 1.2	<0.001
Grains	545.2 ± 4.3	456.5 ± 3.8	288.1 ± 4.5	<0.001	310.6 ± 3.9	404.9 ± 3.4	637.2 ± 3.8	<0.001	508.8 ± 4.1	451.1 ± 3.9	343.8 ± 4.1	<0.001
Nutrients												
Energy (kcal/day)[b]	1638 ± 17	2329 ± 17	3253 ± 17	<0.001	1584 ± 17	2392 ± 17	3115 ± 17	<0.001	1984 ± 21	2317 ± 21	2812 ± 21	<0.001
Fat (g/day)	74.2 ± 0.4	96.3 ± 0.3	130.4 ± 0.4	<0.001	113.4 ± 0.4	104.1 ± 0.4	73.7 ± 0.4	<0.001	103.7 ± 0.5	100.2 ± 0.5	91.8 ± 0.5	<0.001
Protein (g/day)	77.2 ± 0.4	86.6 ± 0.4	103.3 ± 0.4	<0.001	89.7 ± 0.5	90.0 ± 0.4	84.2 ± 0.5	<0.001	89.8 ± 0.4	89.1 ± 0.4	85.2 ± 0.4	<0.001
Carbohydrate (g/day)	357.9 ± 0.9	298.2 ± 0.8	204.0 ± 1.0	<0.001	258.6 ± 1.3	277.1 ± 1.1	347.0 ± 1.3	<0.001	272.5 ± 1.3	285.7 ± 1.3	317.5 ± 1.3	<0.001
Dietary fiber (g/day)	25.9 ± 0.2	22.8 ± 0.1	18.7 ± 0.2	<0.001	21.2 ± 0.2	22.3 ± 0.2	24.2 ± 0.2	<0.001	17.8 ± 0.1	21.9 ± 0.1	28.5 ± 0.1	<0.001
Fructose (g/day)	26.1 ± 0.3	17.4 ± 0.3	7.0 ± 0.3	<0.001	18.9 ± 0.3	16.1 ± 0.3	16.7 ± 0.3	<0.001	8.0 ± 0.2	14.2 ± 0.2	32.0 ± 0.2	<0.001
Calcium (mg/day)	1097 ± 12	976 ± 11	752 ± 13	<0.001	846 ± 12	866 ± 10	1308 ± 12	<0.001	946 ± 11	951 ± 11	957 ± 11	<0.001
Vitamin D (µg/day)	17.3 ± 0.6	35.0 ± 0.6	62.8 ± 0.7	<0.001	52.9 ± 0.7	37.2 ± 0.6	21.9 ± 0.7	<0.001	43.0 ± 0.7	37.6 ± 0.6	30.9 ± 0.7	<0.001
Folate (µg/day)	669.9 ± 3.2	573.7 ± 2.8	426.0 ± 3.4	<0.001	457.5 ± 2.9	531.9 ± 2.5	738.4 ± 2.8	<0.001	558.8 ± 3.4	564.8 ± 3.3	557.2 ± 3.4	<0.05
Caffeine (mg/day)	101.8 ± 2.9	103.1 ± 2.5	94.7 ± 3.0	0.27	99.2 ± 2.9	109.5 ± 2.5	82.7 ± 2.8	<0.001	91.5 ± 2.6	102.5 ± 2.5	103.5 ± 2.6	<0.01

[a] Data are mean ± standard error (SE)

[b] Energy was not adjusted

[c] Obtained from ANCOVA

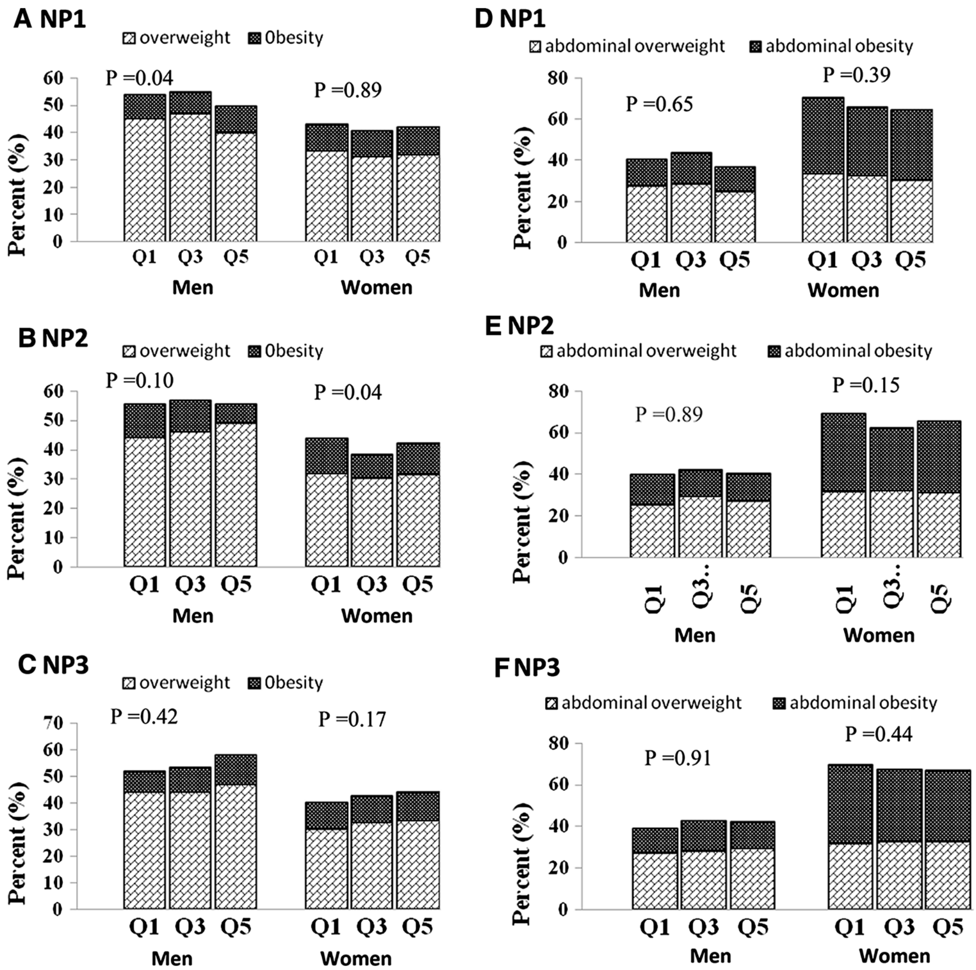

Fig. 1 Prevalence of general and abdominal overweight and obesity among male and female participants based on quintiles for the first, second and third nutrient pattern (NP); overweight and obesity were defined as BMI = 25–29.9 and ≥30 kg/m^2, respectively, and abdominal overweight was defined as waist circumference of 80–88 cm for women and 94–102 cm for men; abdominal obesity was defined as waist circumference >88 cm for women and >102 cm for men. Prevalence of overweight and obesity was significantly different across quintiles for the first nutrient pattern for men and second nutrient pattern for women. No other significant differences were seen in the prevalence of general and abdominal obesity across quintiles of major nutrient patterns

the first nutrient pattern, compared with those in the first quintile, individuals in the fifth quintile were younger, less likely to be females and educated, and more likely to be current smokers. Within the second nutrient pattern, participants in the fifth quintile were more likely to be males and educated, and less likely to be married and breakfast skippers compared with those in the first quintile. Greater adherence to the third nutrient pattern was significantly associated with older age, female gender, greater education and more physical activity. Compared with those in the first quintile of this pattern, subjects in the fifth quintile were less likely to be married, current smokers, breakfast skippers and more likely to be of small family sizes and home owners.

Multivariable-adjusted intakes of selected food groups and nutrients across categories of major nutrient patterns are provided in Table 2. Within the first nutrient pattern, compared with those in the first quintile, individuals in the fifth quintile had higher intakes of vegetables, dairy, white, red and processed meats, legumes and nuts, total energy, dietary fats, proteins and vitamin D and lower intakes of fruits, grains, carbohydrates, dietary fiber, fructose, calcium and folate. Conversely, greater adherence to the second nutrient pattern was associated with higher intakes of grains, total energy, carbohydrates, dietary fiber, calcium and folate and lower intakes of other food groups and nutrients. Within the third nutrient pattern, individuals in the fifth quintile had higher intakes of fruits, vegetables, dairy, legumes and nuts, total energy, carbohydrates, dietary fiber, fructose, calcium and caffeine and lower intakes of white, red and processed meats, grains, fats, proteins, vitamin D and folate, compared with those in the first quintile.

Prevalences of overweight and obesity were significantly different across quintiles of the first nutrient pattern in men (Fig. 1a), and of the second nutrient pattern among women (Fig. 1b). No other significant differences were seen in the prevalence of general and abdominal obesity across quintiles of major nutrient patterns.

Multivariable-adjusted means of anthropometric measures across quintiles of nutrient pattern scores are summarized in Table 3. Neither in crude nor in adjusted models, we observed significant differences in anthropometric measures across quintiles of the first nutrient pattern; however, after adjustment for potential confounders in the fully

Table 3 Gender-stratified multivariable-adjusted means for anthropometric measures across quintiles of nutrient pattern scores

	First nutrient pattern				Second nutrient pattern				Third nutrient pattern			
	Q1	Q3	Q5	P^c	Q1	Q3	Q5	P	Q1	Q3	Q5	P
Men												
Weight												
Crude	75.1 ± 0.5	76.1 ± 0.5	75.9 ± 0.4	0.31	76.0 ± 0.5	76.7 ± 0.5	76.0 ± 0.5	0.68	75.4 ± 0.5	76.5 ± 0.5	76.7 ± 0.6	0.31
Model I[a]	75.1 ± 0.6	76.1 ± 0.5	75.9 ± 0.5	0.31	76.1 ± 0.6	76.7 ± 0.5	75.9 ± 0.5	0.69	75.4 ± 0.5	76.6 ± 0.5	76.7 ± 0.6	0.31
Model II[b]	74.8 ± 0.7	76.2 ± 0.6	76.8 ± 0.6	0.09	77.2 ± 0.8	76.9 ± 0.6	76.0 ± 0.6	0.20	76.1 ± 0.6	76.9 ± 0.6	76.4 ± 0.7	0.79
BMI												
Crude	25.3 ± 0.2	25.4 ± 0.1	25.2 ± 0.1	0.45	25.5 ± 0.2	25.6 ± 0.2	25.4 ± 0.1	0.40	25.2 ± 0.1	25.4 ± 0.1	25.7 ± 0.2	0.23
Model I	25.2 ± 0.2	25.4 ± 0.2	25.3 ± 0.2	0.53	25.4 ± 0.2	25.6 ± 0.2	25.4 ± 0.2	0.49	25.2 ± 0.1	25.4 ± 0.1	25.8 ± 0.2	0.1
Model II	25.1 ± 0.2	25.3 ± 0.2	25.5 ± 0.2	0.47	25.8 ± 0.2	25.6 ± 0.2	25.2 ± 0.2	0.12	25.2 ± 0.2	25.4 ± 0.2	25.5 ± 0.2	0.43
Waist circumference												
Crude	91.4 ± 0.6	92.1 ± 0.5	90.7 ± 0.5	0.36	91.4 ± 0.6	91.5 ± 0.5	91.5 ± 0.5	0.99	91.2 ± 0.5	91.9 ± 0.5	92.0 ± 0.6	0.59
Model I	91.4 ± 0.6	92.1 ± 0.5	90.7 ± 0.6	0.44	91.1 ± 0.7	91.5 ± 0.5	91.8 ± 0.6	0.96	91.1 ± 0.5	91.9 ± 0.5	92.1 ± 0.6	0.48
Model II	90.9 ± 0.8	91.8 ± 0.7	91.5 ± 0.7	0.80	91.6 ± 0.8	91.9 ± 0.7	91.2 ± 0.7	0.72	91.6 ± 0.6	91.8 ± 0.6	91.9 ± 0.7	0.91
Women												
Weight												
Crude	63.4 ± 0.3	63.5 ± 0.4	63.2 ± 0.4	0.87	64.4 ± 0.4	62.2 ± 0.4	63.5 ± 0.4	0.001	62.9 ± 0.4	63.8 ± 0.4	64.0 ± 0.3	0.05
Model I	63.0 ± 0.4	63.5 ± 0.4	63.8 ± 0.5	0.86	64.2 ± 0.4	62.2 ± 0.4	63.3 ± 0.4	0.003	62.6 ± 0.4	63.7 ± 0.4	64.3 ± 0.4	0.004
Model II	63.1 ± 0.5	63.1 ± 0.4	62.9 ± 0.6	0.99	63.7 ± 0.5	62.4 ± 0.4	63.4 ± 0.5	0.29	62.8 ± 0.5	62.9 ± 0.5	63.9 ± 0.4	0.11
BMI												
Crude	24.8 ± 0.1	24.6 ± 0.1	25.2 ± 0.1	0.36	25.1 ± 0.1	24.2 ± 0.1	24.6 ± 0.1	<0.001	24.5 ± 0.1	24.8 ± 0.1	24.8 ± 0.1	0.04
Model I	24.6 ± 0.2	24.6 ± 0.1	24.9 ± 0.2	0.56	24.9 ± 0.1	24.2 ± 0.1	24.8 ± 0.2	0.002	24.3 ± 0.2	24.8 ± 0.1	25.0 ± 0.1	<0.001
Model II	24.6 ± 0.2	24.4 ± 0.2	24.5 ± 0.2	0.96	24.7 ± 0.2	24.2 ± 0.2	24.6 ± 0.2	0.21	24.4 ± 0.2	24.4 ± 0.2	24.9 ± 0.2	0.004
Waist circumference												
Crude	85.3 ± 0.4	84.6 ± 0.4	84.7 ± 0.5	0.50	85.8 ± 0.4	83.5 ± 0.5	84.6 ± 0.5	0.01	85.8 ± 0.51	84.9 ± 0.5	84.2 ± 0.4	0.12
Model I	84.6 ± 0.5	84.6 ± 0.4	85.6 ± 0.6	0.55	85.2 ± 0.5	83.5 ± 0.5	85.1 ± 0.5	0.05	85.6 ± 0.5	84.8 ± 0.5	84.5 ± 0.4	0.44
Model II	84.4 ± 0.6	84.3 ± 0.5	85.1 ± 0.7	0.58	84.6 ± 0.6	83.4 ± 0.5	84.8 ± 0.6	0.38	85.1 ± 0.6	84.1 ± 0.5	83.8 ± 0.5	0.7

Data are mean ± standard error (SE)

[a] Model I: adjusted for age and energy intake

[b] Model II: additionally adjusted for marital status, education, family size, smoking status, physical activity, breakfast skipping and home ownership

[c] Obtained from ANCOVA

Table 4 Odds ratio (95 % CI) for general and abdominal 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												
General obesity												
Crude	1	0.94 (0.60–1.50)	1.15 (0.75–1.75)	0.34	1	0.96 (0.64–1.43)	0.55 (0.36–0.85)	0.02	1	1.20 (0.80–1.80)	1.41 (0.93–2.15)	0.17
Model I[a]	1	1.14 (0.70–1.84)	1.80 (1.05–3.10)	0.02	1	0.95 (0.61–1.48)	0.54 (0.32–0.94)	0.06	1	1.26 (0.84–1.90)	1.61 (1.04–2.50)	0.05
Model II[b]	1	0.97 (0.53–1.76)	1.84 (0.95–3.59)	0.03	1	0.75 (0.44–1.29)	0.39 (0.20–0.76)	0.04	1	1.20 (0.71–2.01)	1.77 (1.04–3.04)	0.09
Abdominal obesity												
Crude	1	1.19 (0.78–1.81)	0.89 (0.59–1.35)	0.75	1	0.83 (0.55–1.26)	0.85 (0.57–1.26)	0.53	1	1.25 (0.85–1.84)	1.09 (0.71–1.66)	0.67
Model I	1	1.23 (0.79–1.90)	0.96 (0.58–1.60)	0.88	1	0.86 (0.55–1.36)	0.91 (0.55–1.51)	0.85	1	1.27 (0.86–1.88)	1.13 (0.73–1.76)	0.51
Model II	1	1.21 (0.71–2.04)	1.14 (0.62–2.09)	0.30	1	1.02 (0.59–1.77)	0.87 (0.46–1.64)	0.90	1	1.35 (0.87–2.11)	1.15 (0.69–1.90)	0.36
Women												
General obesity												
Crude	1	0.94 (0.72–1.22)	1.03 (0.80–1.33)	0.97	1	0.67 (0.49–0.93)	0.88 (0.64–1.21)	0.16	1	0.98 (0.70–1.39)	1.04 (075–1.45)	0.83
Model I	1	1.08 (0.76–1.53)	1.38 (0.86–2.19)	0.18	1	0.69 (0.49–0.98)	0.93 (0.62–1.40)	0.44	1	1.02 (072–1.45)	1.15 (0.81–1.63)	0.46
Model II	1	1.06 (0.67–1.68)	1.19 (0.65–2.18)	0.32	1	0.87 (0.55–1.37)	0.95 (0.55–1.63)	0.53	1	0.80 (0.50–1.28)	1.18 (0.74–1.88)	0.40
Abdominal obesity												
Crude	1	0.86 (0.69–1.07)	0.89 (0.70–1.13)	0.14	1	0.73 (0.58–0.92)	0.86 (0.69–1.09)	0.08	1	0.88 (0.69–1.12)	0.85 (0.67–1.08)	0.12
Model I	1	0.94 (0.74–1.20)	1.10 (0.80–1.52)	0.79	1	0.79 (0.61–1.01)	1.00 (0.74–1.33)	0.75	1	0.91 (0.71–1.16)	0.93 (0.72–1.19)	0.46
Model II	1	0.88 (0.64–1.21)	0.92 (0.61–1.40)	0.76	1	0.90 (0.64–1.25)	1.20 (0.82–1.77)	0.41	1	0.78 (0.58–1.06)	0.86 (0.64–1.17)	0.56

Data are OR (95 % CI)

[a] Model I: adjusted for age and energy intake

[b] Model II: additionally adjusted for marital status, education, family size, smoking status, physical activity, breakfast skipping and home ownership

adjusted model, men in the fifth quintile of this nutrient pattern tended to have higher weight than those in the first quintile (76.8 ± 0.6 vs. 74.7 ± 0.7 kg, $P = 0.09$). Comparing extreme quintiles of the second nutrient pattern, we found no significant difference in mean weight, BMI and waist circumference among men; however, women in the fifth quintile of this nutrient pattern had significantly lower means of anthropometric measures than those in the first quintile. When the potential confounders were taken into account, these associations became nonsignificant. The third nutrient pattern was not associated with any changes in anthropometric measures in men, while women in the fifth quintile had higher mean weight and BMI than those in the first quintile. The positive association between this nutrient pattern and BMI remained significant, even after controlling for potential confounders. No significant difference in mean waist circumference was seen across quintiles of the third nutrient pattern in women.

Men in the fifth quintile of the second nutrient pattern were 45 % less likely to be generally obese [odds ratio (OR) 0.55, 95 % confidence interval (95 % CI) 0.36–0.85] (Table 4). The association strengthened in the fully adjusted model (OR 0.39, 95 % CI 0.20–0.76). Although the protective association between the second nutrient pattern and obesity was seen among females in the third quintile compared with those in the first quintile, the association became nonsignificant in the fully adjusted model (OR 0.87, 95 % CI 0.55–1.37). When the confounders were taken into account, we found a significant positive association between adherence to the third nutrient pattern and general obesity in men (OR 1.77, 95 % CI 1.04–3.04), but not in women (OR 1.18; 95 % CI 0.74–1.88) for individuals in the fifth quintile. No association was observed between patterns of nutrient intake and abdominal obesity in both genders (Table 4).

Discussion

In this cross-sectional study in a large cohort of Iranian adults, we found a significant protective association between adherence to the second nutrient pattern (higher amount of thiamine, betaine, starch, folate, iron, selenium, niacin, calcium and manganese) and odds of general obesity in men, but not in women. In contrast, the third nutrient pattern (higher amount of glucose, fructose, sucrose, vitamin C, potassium, total dietary fiber, copper and vitamin K) was positively associated with the risk of general obesity among men, but not in women. No overall associations were seen between patterns of nutrient intake and abdominal obesity in both genders. To the best of our knowledge, this is the first study examining the association between distinct patterns of nutrient intake and obesity.

Although associations between dietary patterns and risk of chronic conditions have received increased attention, few data are available linking patterns of nutrient intake and risk of non-communicable diseases [4–6, 8–11]. Since nutrients are universal and their structures are not affected by behaviors and customs (e.g., food preparation), unlike those of foods, the evaluation of patterns of nutrient ingestion in different parts of the world [3] may provide new insights into the relationship(s) between nutrient patterns and diseases across different geographical regions [7].

The present study revealed, for the first time, the existence of three major nutrient patterns in a large Middle Eastern population. Previous studies on nutrient patterns have reported similar associations with different types of cancer [4–6, 9, 10, 26, 32] and osteoporosis [11]. Nutrients included in nutrient pattern analyses in previous studies varied between 19 and 30 nutrients and differed amongst studies based on the outcome variable(s) of interest. We attempted to include a maximum number of obesity-related nutrients and bioactive compounds (38 in total) in our analysis. For example, in contrast to previous studies, we included free sugars (fructose, glucose and sucrose) in the factor analysis, since there is a large body of evidence relating monosaccharide intake to obesity [33, 34].

In the current study, we found a significant protective association between a pattern of nutrient intake that was greatly loaded on thiamine, betaine, starch, folate, iron, selenium, niacin, calcium and manganese and odds of general obesity in men, but not in women. Except for iron and calcium, the primary source of all nutrients in this pattern might be plant foods, which has previously been related to decreased risk of obesity [35]. Dietary intakes of betaine [36], folate [37, 38], iron [39], selenium [40] and calcium [41] have been inversely related to obesity in previous studies. In contrast, some other nutrients in this pattern, such as thiamin [20] and niacin [42], have been positively related to obesity. B-vitamins may stimulate appetite; thus, their long-term consumption may trigger excessive energy intake and weight gain [43]. Starch was also highly represented in this nutrient pattern. In contrast to free sugars, there is a controversy about the association between starch consumption and obesity among studies because starch is a complex carbohydrate mostly present in solid foods with fiber and other food components [34, 44]. The combination of obesity-inducing nutrients and those protecting against body fat accumulation in this nutrient pattern makes interpretation somewhat difficult; however, taken together, our findings on the association between nutrient patterns and obesity support previous findings on the link between dietary patterns and obesity [45–47], and underline the validity of the nutrient pattern approach in assessing diet–disease relations. Furthermore, our findings indicate that complex, previously unrecognized, interactions may take place between highly loaded nutrients (both obesity-inducing and protective) that require much further research. Finally, the inverse association that we found between nutrients loaded in the second pattern and obesity might provide an excellent basis from which to evaluate obesity-protective effects of multiple-nutrient supplementation in future studies.

Both males and females in the top quintile of the third nutrient pattern, which was mainly loaded on glucose, fructose, sucrose, vitamin C, potassium, total dietary fiber, copper and vitamin K, had higher BMIs than participants in the lowest quintile; however, in logistic regression models, this association remained significant only in men. Although an inverse association between dietary fiber [44], potassium [48] and vitamin K status [49] and obesity has been reported in previous studies, the presence of free sugars in this nutrient pattern may have resulted in an obesity-inducing effect; thus, it appears that free sugars increase the odds of obesity even when co-ingested with nutrients that may assist to protect against obesity. Although assessment of the effects of individual nutrient intakes in the framework of a nutrient pattern is impossible, it appears that nutrients with greater factor loadings, along with the synergistic effects of other nutrients, determine the contribution of a given pattern to obesity. Thus, based on our findings, people should be clinically advised not to consume large amounts of simple sugars in their diets, regardless of overall energy intake.

The reasons for the observed gender disparity in the associations between nutrient patterns with obesity are unclear, but may, at least in part, in the differential influence of gonadal steroids on body composition and appetite; behavioral, sociocultural and genetic factors may also play a role [50]. Another reason for this discrepancy might be the difference in accuracy of dietary assessment among females and males. Thus, actual food choices [51], self-reported preferences for foods [52] and accuracy of dietary assessment [53] may all vary by gender. For example, European women appear to eat more fruit, vegetables and dietary fiber than men [51]; gender was reported to be the most personal characteristic that related to intake measurement errors for food groups [53]. This may especially be the case for FFQs based on the Willett format; for these, a tendency to underestimate and overestimate nutrient intakes in men and women, respectively, has been reported [54].

None of the patterns of nutrient intakes that we identified were associated with abdominal adiposity. Although data about nutrient intakes and abdominal obesity are scarce, positive associations between dietary intakes of fructose [55] or trans fatty acids [56] with abdominal fat accumulation have been reported. In addition, dietary fiber [56], calcium [22], vitamin D [57] and conjugated linoleic acid [58] consumption have been found to be inversely related to abdominal obesity. Based on these findings, we expected to observe an inverse association between the second nutrient pattern and abdominal obesity, and a positive association between the third dietary pattern and abdominal fat accumulation. The lack of significant associations between nutrient patterns and abdominal obesity in this study might have several reasons. We defined abdominal obesity based on WC measurements. While some studies have introduced WC as a better anthropometric measure than waist-to-hip and waist-to-height ratios for central fat accumulation [59, 60], others have failed to confirm this [61]. This is of particular importance in Middle Eastern countries, where an exact definition of abdominal obesity still needs further investigation. The current criteria to define abdominal obesity are based mainly on studies conducted in Western countries [28, 29], and it is possible that these may be different among Middle Eastern populations (e.g., Iranian adults). Furthermore, we assessed all anthropometric measures, including WC, through self-reported data. While our validation study revealed a significant correlation between self-reported and measured data for waist circumference, the association was not as strong as for weight and height. Therefore, self-reporting may have caused some misclassification of participants across categories of abdominal obesity.

Several limitations need to be considered when interpreting our findings. Due to the cross-sectional design of SEPAHAN, one cannot infer causality; thus, our findings need to be confirmed in prospective studies. Furthermore, individuals with certain anthropometric features may have changed their diet to manage their obesity. However, such residual confounding effects would tend to attenuate the risk estimates; thus, the true results may be even stronger than those found. The role of other residual confounding variables (e.g., menopausal status, hormone therapy) cannot be excluded, as information on these was not collected. Although we used a validated FFQ for dietary assessment, some degree of measurement error and misclassification must be considered. However, nutrient patterns derived from FFQ data can provide valid information on nutrient patterns compared to 24-h dietary recalls [62]. Due to the lack of a complete Iranian food composition table, we based our dietary analyses on the USDA nutrient databank. While this may have led to errors in calculating individuals' nutrient intakes, it did not appear to affect participants' rankings based on nutrient intakes. The subjective or arbitrary decisions in factor analysis, such as choice of nutrients to be included in analysis, number of factors to be extracted and selecting the method of rotation, should be considered while interpreting the results [63]. For example, selecting different numbers of nutrients to be included in factor analysis might result in different nutrient loading and different numbers of derived factors; selecting different methods of rotation might affect the number of factors derived and the nutrients loaded in each factor [63]. Finally, SEPAHAN study participants were adults working in 50 different health centers across Isfahan province; therefore, generalization of our findings to the general Iranian population must be done with caution.

In conclusion, we found evidence indicating that a nutrient pattern characterized by high consumption of thiamine, betaine, starch, folate, iron, selenium, niacin, calcium and manganese was associated with lower odds of general obesity, while a pattern of nutrient intake with high amounts of glucose, fructose, sucrose, vitamin C, potassium, total dietary fiber, copper and vitamin K was associated with greater odds of general obesity, in men, but not in women. Prospective studies are required to confirm these findings and to evaluate any causal relationships between adherence to particular nutrient patterns and obesity.

Acknowledgments The authors are thankful to participants of SEPAHAN project and authorities of Isfahan University of Medical Sciences for their excellent cooperation. We also appreciate the research council of Food Security Research Center for funding this project.

Conflict of interest Authors had no personal or financial conflicts of interest to declare.

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