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The Association between Food Patterns and the Metabolic Syndrome Using Principal Components Analysis: The ATTICA Study

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ABSTRACT

Background Dietary habits have been associated with the prevalence of the metabolic syndrome.

Objective The associations between foods or food patterns and the characteristics of the metabolic syndrome were evaluated.

Design Cross-sectional survey.

Subjects During 2001 to 2002, 1,514 men (aged 18 to 87 years) and 1,528 women (aged 18 to 89 years) without any clinical evidence of cardiovascular disease were randomly enrolled, from the Attica region in Greece.

Main outcome measures Dietary habits were evaluated using a semiquantitative, food frequency questionnaire. Characteristics of the metabolic syndrome (ie, blood pressure, waist circumference, glucose, triglycerides, and high-density lipoprotein cholesterol) were also measured.

Statistical analysis Principal components analysis was applied to extract dietary patterns from 22 foods or food groups. Multivariate regression analysis evaluated the associations between the extracted dietary patterns and characteristics of the metabolic syndrome.

Results Six components were derived explaining 56% of the total variation in intake. Component 1 was characterized by the consumption of cereals, fish, legumes, vegetables, and fruits (explained variation 19.7%); component 2 was characterized by the intake of potatoes and meat (explained variation 11.7%), component 6 was characterized by alcohol intake (explained variation 4.8%), whereas the other components were mainly characterized by consumption of dairy and sweets. After adjusting for various confounders, component 1 was inversely associated with waist circumference, systolic blood pressure, triglycerides, positively associated with high-density lipoprotein cholesterol levels, and inversely with the likelihood of the metabolic syndrome (odds ratio [OR] 0.87, 95% confidence interval [CI] 0.79 to 0.97), whereas components 2 and 6 were positively correlated with the previous indexes, and the likelihood of having the metabolic syndrome (OR 1.13, 95% CI 1.05 to 1.21 and OR 1.26, 95% CI 1.21 to 1.33).

Conclusions A dietary pattern that includes cereals, fish, legumes, vegetables, and fruits was independently associated with reduced levels of clinical and biological markers linked to the metabolic syndrome, whereas meat and alcohol intake showed the opposite results.

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It is well appreciated that the metabolic syndrome is a condition that promotes atherosclerosis and increases the risk of cardiovascular disease (1-5). Each abnormality of the syndrome (ie, atherogenic dyslipidemia, a prothrombotic state, insulin resistance, hypertension, and abdominal obesity) enhances atherosclerosis independently, but when clustered together, these metabolic disorders are increasingly atherogenic and increase the risk of cardiovascular morbidity and mortality (1). The National Cholesterol Education Program Adult Treatment Panel III presents the metabolic syndrome as an enhancer of cardiovascular risk beyond elevated low-density lipoprotein cholesterol (2). As indicated in several studies, among several factors that influence the risk of developing the metabolic syndrome, dietary habits seem to play an important role (6-9). At this point it should be mentioned that the majority of studies followed the approach of assessing single nutrients or food items, instead of assessing dietary patterns; however, people do not eat isolated nutrients, they consume meals consisting of a variety of foods with complex combinations of nutrients. Thus, it has been suggested to use a holistic dietary approach to disease prevention (10,11). Multivariate techniques (12), including cluster, principal components, and factor analysis, have emerged as methods to empirically derive dietary (or food) patterns and possibly explain nutrient–disease relations (13). The purpose of principal component analysis is to derive a number of independent linear combinations (principal components) of a set of foods or food groups that retain as much of the information of original dietary habits. In other words, principal components analysis evaluates the correlations between all food intake variables and reveals similarities in the habits of people. Cluster analysis group foods or food groups that are consumed with similar frequency into a set of prespecified number of food categories. Thus, principal component analysis identifies groups of dietary habits that have not been set a priori, as in cluster analysis and for each extracted component uses all the information provided. Afterward, the application of the classical statistical methods, like multiple regression analysis, may reveal if a food or dietary pattern (what we call a component) is associated with a set of surrogate markers of a disease or hard outcomes like the metabolic syndrome. Several studies have already used principal components analysis, and have empirically derived a healthful food pattern that is high in fruit, vegetables, seafood, fiber, and other healthful foods (14,15), but none of these studies have associated food patterns with the metabolic syndrome components.

In our study, the hypothesis tested was whether or not the dietary patterns of 3,042 apparently healthy men and women (16), as derived from multivariate analysis, were related to the components of the metabolic syndrome. Specifically, using principal components analysis a given set of food-variables was transformed into a reduced set of uncorrelated food patterns (components). Then, using as dependent outcome the characteristics of the syndrome (ie, blood pressure, triglyceride level, high-density lipoprotein [HDL] cholesterol level, and waist circumference), the effect of the extracted food patterns was tested against the aforementioned characteristics. In previous analyses of the ATTICA study the effect of the dietary pattern (ie, the Mediterranean diet) has been evaluated in relation to the prevalence of the metabolic syndrome using classic methods of data analysis (16). However, food-specific analyses in relation to the characteristics of the syndrome have not been done because of methodological limitations of the methods (ie, collinearity of the food variables). In this work, the previous information has been expanded, and using a multivariate analytic technique various dietary patterns were derived and evaluated in relation to the specific components of the metabolic syndrome.

SUBJECTS AND METHODS

Study Population

The ATTICA study was a health and nutrition survey carried out in the province of Attica in Greece (including 78% urban and 22% rural areas). Data collection started in May 2001 and ended in December 2002. The sampling was random, multistage (by city) and it was based on the age–sex distribution of the province of Attica provided by the Hellenic National Statistical Service (census of 2001). In each area the information was collected during all four seasons to eliminate the potential confounding effect of seasonality on dietary habits. During the study period, 4,056 inhabitants from the area and without any clinical evidence for cardiovascular disease were randomly selected to participate in the study; 3,042 were enrolled. Thus, 25% of those who were eligible did not participate because of several reasons (eg, lack of time or unexpected reasons that forced them to cancel the interview) that were not related to the hypothesis tested. Of them, 1,518 were men (aged 46±13 years) and 1,524 were women (aged 45±13 years). The subjects did not report chronic viral infections, cold or flu, acute respiratory infection, dental problems, or any type of surgery in the week preceding the study. All participants were interviewed by trained personnel (cardiologists, general practitioners, food and nutrition professionals, and nurses) who used a standard questionnaire with closed-ended questions.

The institutional review boards of the First Cardiology Clinic of Athens Medical School approved the ATTICA study protocol, and all subjects gave informed consent for their participation.

Dietary Assessment

Dietary intake was assessed using a validated semiquantitative food frequency questionnaire (17). In particular, study participants were instructed by trained food and nutrition professionals to complete the questionnaire that included 156 foods and beverages commonly consumed in Greece. Alcohol consumption was quantified in wineglasses (100 mL). One wineglass was assumed equal to 12 g ethanol concentration. In this work, we focused on major food groups, like consumption of whole bread, pasta, rice, and other nonrefined cereals, fruits, greens, vegetables, legumes, potatoes, eggs, big or small fish, various types of meat and its products, poultry, sweets, and dairy products (eg, cheese, yogurt, and milk). Portions of foods were specified (eg, small, normal, and large) and in some cases photos assisted the participant to decide the exact portion of food consumed. Mixed foods were taken into account and assigned into the respective food groups. Added fat was recorded, but not used in the analyses due to difficulties in the quantification and because a large proportion of participants (about 95%) reported use of olive oil as the main added fat. Thus, the fat variable was almost constant.

Sociodemographic and Other Lifestyle Variables

As proxies of socioeconomic status, annual income (low, moderate, good, and very good for living) during the past 3 years and the education level of the participants in years of school was recorded. Current smokers were defined as those who smoked at least one cigarette per day; former smokers were defined as those who had stopped smoking for at least 1 year and the rest of the participants were defined as nonsmokers. Occasional smokers (fewer than seven cigarettes per week) were recorded and combined with current smokers due to their small sample size. For the ascertainment of physical activity status the International Physical Activity Questionnaire (18) was used, which is suitable for assessing population levels of self reported physical activity. The short version of the International Physical Activity Questionnaire (nine items) that was used provided information on weekly time spent walking, in vigorous activity, moderate-intensity activity, and in sedentary activity. Participants were instructed to refer to all domains of physical activity during a usual week of the past year. Participants who did not report any physical activities were defined as sedentary.

Anthropometric, Clinical, and Biochemical Characteristics

Standing height was measured once using a portable stadiometer (Holtain Ltd, Crymmych, Pembrookshire, UK). Body weight was also measured once using a weighing scale (HoMedics Co, Kent, UK). All measurements were performed by the study investigators. Body mass index (BMI) was calculated as kg/m^2. According to standard guidelines (19), obesity was defined as BMI $>$29.9. Arterial blood pressure was measured three times then averaged, at the end of the physical examination with subject in sitting in a chair. All participants were at rest at least 30 minutes. Patients whose average blood pressure levels were greater or equal to 140/90 mm Hg or taking antihypertensive medication were classified as hypertensive. Blood samples were collected from the antecubital vein between 8 and 10 AM, after 12 hours of fasting and avoidance of alcohol. Total and HDL cholesterol and triglyceride levels were measured using chromatographic enzymic method (Technicon Automatic Analyzer RA 1,000, Tarrytown, NY). The intra- and interassay coefficients of variation of cholesterol and triglycerides did not exceed 4%. Hypercholesterolemia was defined as total serum cholesterol levels $>$200 mg/dL (5.2 mmol/L) or the use of lipid-lowering agents. Blood glucose levels were measured immediately after collection with a Beckman Glucose Analyzer (Beckman Instruments, Fullerton, CA). Blood glucose levels $>$125 mg/dL (6.9 mmol/L) or the use of hypoglycemic agents or insulin to control glucose levels, characterized people as having type 2 diabetes mellitus.

The metabolic syndrome was defined according to recent National Cholesterol Education Program Adult Treatment Panel III criteria (2); a diagnosis can be established if three or more of the following five factors are present: waist circumference $>$102 cm ($>$40 in) for men or $>$88 cm ($>$37 in) for women; triglyceride level $>$150 mg/dL ($>$1.7 mmol/L); HDL cholesterol level $<$40 mg/dL ($<$1.00 mmol/L) for men or $<$50 mg/dL ($<$0.13 mmol/L) for women; blood pressure $>$130/85 mm Hg; or fasting glucose $>$100 mg/dL ($>$5.6 mmol/L).

STATISTICAL METHODS

Descriptive and Basic Statistical Analyses

Continuous variables are presented as mean values$\pm$ standard deviation and categorical variables are presented as absolute and relative frequencies. Associations between categorical variables were tested by the calculation of χ^2 test, whereas differences between categorical and several biochemical, clinical, and nutritional variables were tested by the use of the Student *t* and Mann-Whitney U criteria (for the normally distributed and the skewed variables, respectively). Multiple regression analysis was applied to model the associations between multiple dependent variables (ie, components of the metabolic syndrome) and the extracted (calculated), from the principal components analysis, food patterns. Pillai's trace was used to evaluate overall the association between food components and the metabolic syndrome indexes. This statistic is a positive-valued measure of the association of the specific food component on the set of characteristics of the metabolic syndrome, with larger values indicating higher association. The interactions between the food components and various potential confounders (eg, sex and age), were also tested. Residuals and Cook's distances were used to check model's assumptions. Finally, multiple logistic regression analysis was used to evaluate the likelihood of having the metabolic syndrome as a function of the food components. Deviance residuals were used to check models' goodness of fit. The potential confounding effects of various sociodemographic items, lifestyles, and other variables, as well as the presence of any significant interactions between the aforementioned variables and food components, were also tested. All reported *P* values are based on two-sided tests and compared to a significance level of 5%. STATA software was used for all the statistical calculations (version 8, 2003, STATA Corp, College Station, TX).

Food Component Derivation

To obtain food patterns the principal components analysis was used (20). It is known that for the results from a principal components analysis to have some value, strong correlations between the variables should exist. The correlation matrix of the food variables used in our analysis showed that there were several correlation coefficients $r>0.4$, indicating that food variables were correlated together and, therefore, a principal components analysis could be effective for assessing food patterns. In addition, the Φ coefficient (a measure of the association of categorical variables) was 0.89, which is close to one and implies high interrelationships between food variables.

From the entire database 22 foods and food groups were created mainly according to their macronutrient composition (eg, cereals include rice, oats, wheat, and corn). The food or food groups used in all analyses are presented in Table 1. Food groups or foods that entered into the principal components analysis were coded as servings per month. The principal components analysis procedure in STATA was used to perform the analysis. The orthogonal rotation (rotate with varimax option) was used to derive optimal noncorrelated components (food patterns). The information was rotated to increase the representation of each food or food group to a component

Table 1. Score coefficients[a] derived from principal components analysis regarding foods or food groups consumed by Greek ATTICA study participants

	Component[b]					
	1	**2**	**3**	**4**	**5**	**6**
Alcoholic beverages	0.043	0.008	0.153	−0.051	0.250	**−0.409**
Milk, whole	−0.125	0.021	0.107	**0.566**	0.080	0.340
Yogurt, whole	0.046	0.031	−0.020	**0.617**	0.116	0.113
Feta cheese	0.103	0.037	0.002	**0.549**	0.061	−0.270
Other cheese	0.016	−0.084	0.058	**0.448**	0.273	−0.096
Egg	0.105	0.291	0.060	**0.512**	−0.108	0.165
Bread, pasta, biscuits	0.128	0.174	**−0.215**	0.182	−0.084	−0.190
Cereals	**0.717**	−0.040	0.063	0.004	0.138	0.025
Beef	0.030	**0.576**	0.074	0.042	−0.118	−0.021
Pork	−0.208	**0.479**	0.181	0.052	0.337	−0.155
Other meat	0.038	**0.413**	0.127	0.202	0.248	−0.136
Meat products	0.067	**0.711**	0.055	0.081	0.068	0.048
Poultry	0.108	**0.540**	0.122	−0.273	−0.106	0.283
Fish, small (eg, sardine)	**0.591**	0.004	0.107	0.063	−0.083	−0.105
Fish, big (eg, swordfish)	**0.581**	0.071	0.065	0.005	−0.178	0.084
Potatoes, fried	−0.194	**0.459**	0.131	0.219	0.389	−0.168
Potatoes, boiled/baked	0.358	**0.363**	−0.088	0.055	0.164	−0.084
Greens	**0.650**	−0.060	−0.070	−0.090	0.110	−0.095
Legumes	**0.563**	0.056	0.042	0.244	0.043	0.009
Fruits	**0.534**	−0.010	−0.128	0.067	0.323	0.302
Vegetables	**0.708**	0.041	−0.140	−0.019	0.234	−0.001
Sweets	0.096	0.187	0.062	0.159	**0.599**	0.259
Explained variance (%)	19.7	11.7	8.6	6.2	5.0	4.8

[a]Score coefficients are similar to the correlation coefficients. Higher absolute values indicate that the food variable is correlated with the respective component. Numbers in bold indicate loadings >0.2 (ie, higher correlation of the food group with the component).

[b]Description of the components: component 1=A healthful food pattern; component 2=A high glycemic index and high fat pattern; component 3=A pattern that includes consumption of pasta; component 4=A pattern that is characterized by the intake of dairy products and eggs; component 5=A pattern that is mainly characterized by the consumption of sweets; and component 6=A pattern that represents the consumption of alcohol.

(20). To decide the number of components to retain, the scree plot of the eigenvalues that derived from the correlation matrix of the standardized variables was examined (eigenvalue is a value that indicates the proportion of the variance in consumption explained by each component). According to the Kaiser criterion, the number of components that should be retained from principal components analysis is equal to the number of eigenvalues that are greater than one. In our analysis, a six-component (food patterns) solution was selected because six of the 22 extracted components had eigenvalues greater than one. Based on the principle that the component scores are interpreted similarly to correlation coefficients (thus, higher absolute values indicate that the food variable contributes most to the construction of the component), the food components (patterns) were named according to scores of the foods that correlated most with the factor (scores >0.4).

Because some investigators have found that component solutions may differ by sex (19), the solutions were examined separately for men and women, but the result that included both sexes was retained in our analysis to maximize the statistical power. In addition, the interaction between food components and sex was evaluated in the regression analyses.

RESULTS

The prevalence of the metabolic syndrome was 18%, whereas sex-specific prevalence was 23% in men and 13% in women. An increasing trend of the prevalence of the metabolic was observed by age group in men: 6% in those <35 years old, 24% in those 35 to 65 years old, and 26% in those who are elderly (P for trend <0.001), and in women: 5% in those <35 years old, 15% in those 35 to 65 years old, and 28% in those who are elderly (P for trend <0.001). Table 2 illustrates various characteristics of the participants.

Principal components analysis extracted six components that explained the 56% of the total variation in intake. The scores for the six food components (patterns) are presented in Table 1 (in bold are the coefficients with absolute value >0.4). Because the higher absolute values indicate that the food variable contributes more to the development of the component (20), the following components were derived: a healthful food pattern (component 1), which loaded heavily on low-fat products such as fish, vegetables, legumes, cereals, and fruits; a high glycemic index and high-fat pattern, which included red or white meat and meat products, and potatoes (component 2); a pattern that included consumption of pasta (component 3); a pattern that is characterized by the intake of dairy

Table 2. Sociodemographic, lifestyle, clinical, and biological characteristics of Greek ATTICA study participants

	Men (n=1,514)	Women (n=1,528)	*P* value
Demographic and lifestyle variables	← *Mean±SD*[a] →		
Age (y)	46±13	45±13	0.14
Years of school	12.2±3.6	11.9±3.4	0.03
	Absolute and Relative (%) Frequency	*Absolute and Relative (%) Frequency*	
Current smoker	781 (51%)	596 (39%)	0.001
Former smoker	230 (15%)	100 (7%)	0.001
Physical inactivity	874 (57%)	903 (59%)	0.26
Low–medium income	467 (31%)	564 (37%)	0.001
Clinical characteristics	← *Mean±SD* →		
Body mass index	27.4±4	25.3±5	<0.001
Waist (cm)	97.7±13.1	82.7±13.4	0.001
Systolic blood pressure (mm Hg)	126±38	119±36	<0.001
Diastolic blood pressure (mm Hg)	82±30	76±14	<0.001
Total serum cholesterol (mg/dL)[b]	195±42	191±41	0.01
High-density lipoprotein cholesterol (mg/dL)[b]	44±15	52±14	<0.001
Triglyceride (mg/dL)[c]	138±57	103±56	0.001
Blood glucose (mg/dL)[d]	96±31	90±21	<0.001
	Absolute and Relative (%) Frequency	*Absolute and Relative (%) Frequency*	
Prevalence of obesity	308 (20%)	234 (15%)	0.001
Prevalence of hypertension	563 (37%)	379 (25%)	<0.001
Use of antihypertensive treatment	204 (36%)	178 (47%)	0.001
Prevalence of hypercholesterolemia	701 (46%)	605 (40%)	0.02
Use of lipid lowering agents	346 (49%)	304 (50%)	0.80
Prevalence of diabetes mellitus	110 (8%)	84 (6%)	0.51

[a]SD=standard deviation.
[b]To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.026. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.6. Cholesterol of 193 mg/dL=5.0 mmol/L.
[c]To convert mg/dL triglyceride to mmol/L multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 159 mg/dL=1.80 mmol/L.
[d]To convert mg/dL glucose to mmol/L, multiply mg/dL by 0.0555. To convert mmol/L glucose to mg/dL, multiply mmol/L by 18.0. Glucose of 108 mg/dL=6.0 mmol/L.

products and eggs (component 4); a pattern that is mainly characterized by the consumption of sweets (component 5); and a pattern that represents the consumption of alcohol (component 6). Component 1 was the most dominant food pattern and explained 19.7% of the total variance. Each of the remaining five components explained from 4.8% (component 6) to 11.7% (component 2) of variance in intake.

Component 1 was inversely associated with age ($r=-0.73$, $P=0.019$), and number of cigarettes smoked ($r=-0.11$, $P=0.008$) and positively associated with physical activity status ($r=0.12$, $P=0.001$); component 2 was positively associated with age ($r=-0.035$, $P=0.001$), male sex ($P=0.001$) and inversely associated with income ($r=-0.179$, $P=0.001$) and physical activity level ($r=-0.136$, $P=0.001$). The correlations between characteristics of the participants and the other extracted components are not presented because they explained a small proportion of the total variation in intake.

To evaluate the associations between the extracted components and characteristics of the metabolic syndrome the potential confounding effect of age, sex, physical inactivity, smoking habits, years of school, income, medication or use of special diet, and BMI was taken into account. The results of the multiadjusted multivariate regression analysis for the components of the metabolic syndrome are shown in Table 3; no significant interactions were seen between food components and sex, physical activity, and smoking habits. The Pillai's trace was significant only for component 1 and component 6 ($P<0.001$), indicating that these components were highly associated with the whole spectrum of the investigated characteristics of the syndrome. Specifically, after adjusting for the aforementioned confounders, component 1 was inversely associated with waist circumference, systolic blood pressure, triglycerides and positively associated with HDL-cholesterol levels. Component 2 was positively correlated with waist circumference and inversely correlated with HDL cholesterol levels. Finally, component 6 was positively correlated with waist, systolic blood pressure, blood glucose, and triglyceride level and inversely correlated with HDL cholesterol level. Components 3, 4, and 5 were not associated with indexes of the metabolic syndrome.

The food pattern that is mainly characterized by the consumption of fish, vegetables, legumes, cereals, and fruits (component 1) was associated with 13% lower likelihood of having the metabolic syndrome (odds ratio 0.87), whereas the food pattern that is mainly characterized by the intake of alcoholic beverages, was associated with 26% higher likelihood of having the syndrome (odds ratio 1.26). No other component was associated with prevalence of the metabolic syndrome. All these associations were adjusted for age, sex, phys-

Table 3. Results from multivariate regression analysis of data collected from adult, Greek participants in the ATTICA study that evaluated the association between dietary patterns and factors of the metabolic syndrome[a]

Dependent variable	Parameter	$\beta\pm$Standard error	*P* value
Waist circumference (cm)	**Intercept**	90.071±0.326	0.001
	Component 1: Fish, vegetables, legumes, cereals, and fruits	−0.879±0.283	0.002
	Component 2: Potatoes, red or white meat, and meat products.	0.702±0.281	0.012
	Component 3: Bread, pasta	−0.717±0.385	0.112
	Component 4: Dairy products and eggs	0.110±0.287	0.703
	Component 5: Sweets	0.363±0.286	0.205
	Component 6: Alcoholic beverages	2.182±0.284	0.001
Systolic blood pressure (mm Hg)	**Intercept**	121.737±0.394	0.001
	Component 1: Fish, vegetables, legumes, cereals, and fruits	−0.996±0.342	0.004
	Component 2: Potatoes, red or white meat, and meat products.	0.170±0.339	0.617
	Component 3: Bread, pasta	−0.303±0.345	0.380
	Component 4: Dairy products and eggs	−0.164±0.348	0.638
	Component 5: Sweets	0.238±0.346	0.492
	Component 6: Alcoholic beverages	1.547±0.344	0.001
Blood glucose (mg/dL)[b]	**Intercept**	92.516±0.494	0.001
	Component 1: Fish, vegetables, legumes, cereals, and fruits	0.489±0.429	0.255
	Component 2: Potatoes, red or white meat and meat products.	−0.232±0.425	0.586
	Component 3: Bread, pasta	−0.563±0.433	0.194
	Component 4: Dairy products and eggs	0.528±0.436	0.226
	Component 5: Sweets	0.358±0.434	0.409
	Component 6: Alcoholic beverages	1.553±0.431	0.001
Triglycerides (mg/dL)[c]	**Intercept**	116.549±1.788	0.001
	Component 1: Fish, vegetables, legumes, cereals, and fruits	−2.631±1.550	0.090
	Component 2: Potatoes, red or white meat and meat products.	1.326±1.539	0.389
	Component 3: Bread, pasta	−1.017±1.565	0.210
	Component 4: Dairy products and eggs	4.334±1.576	0.006
	Component 5: Sweets	−1.706±1.568	0.277
	Component 6: Alcoholic beverages	4.550±1.557	0.004
High-density lipoprotein cholesterol (mg/dL)[d]	**Intercept**	48.250±0.306	0.001
	Component 1: Fish, vegetables, legumes, cereals, and fruits	0.431±0.266	0.023
	Component 2: Potatoes, red or white meat, and meat products.	−0.993±0.264	0.001
	Component 3: Bread, pasta	0.268±0.268	0.234
	Component 4: Dairy products and eggs	0.200±0.270	0.459
	Component 5: Sweets	−0.033±0.269	0.902
	Component 6: Alcoholic beverages	−0.831±0.267	0.002

[a]Potential confounders used in all analyses were age, sex, physical inactivity, smoking habits, years of school, income, medication or use of special diet, and body mass index.
[b]To convert mg/dL glucose to mmol/L, multiply mg/dL by 0.0555. To convert mmol/L glucose to mg/dL, multiply mmol/L by 18.0. Glucose of 108 mg/dL=6.0 mmol/L.
[c]To convert mg/dL triglyceride to mmol/L, multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 159 mg/dL=1.80 mmol/L.
[d]To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.026. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.6. Cholesterol of 193 mg/dL=5.00 mmol/L.

ical inactivity, smoking, years of school, income, use of medication, and BMI (Table 4).

DISCUSSION

Using principal components analysis in a sample of 3,042 adult men and women, six components (patterns) were derived that characterize their dietary habits. The first component could be described as the healthful pattern; it had the greatest amount of variety in intake and was inversely related to indexes of the metabolic syndrome. This pattern was associated with 13% lower likelihood of having the syndrome. Regarding the other components, the sixth, which was characterized by consumption of alcoholic beverages, was positively associated with the metabolic syndrome, increasing the odds of getting the syndrome by 26%.

A past year's dietary pattern analysis has emerged as a complementary approach to examining the relationship between diet and the risk of various chronic diseases. Instead of looking at individual nutrients or foods, pattern analysis examines the effects of overall diet and represents a broader picture of food and nutrient consumption. Moreover, this type of analysis reveals similarities and captures extremes in food intake. Thus, dietary patterns seem more predictive of disease risk than individual foods or nutrients. Using multivariate statistical techniques researchers have identified similarities in food consumption among individuals that could be described as a pattern. In our study, using a multivariate

Table 4. Results from logistic regression analysis of data collected from adult. Greek participants in the ATTICA study that evaluated the association between food components and the likelihood of having the metabolic syndrome[a]

	Odds ratio	95% Confidence interval	*P* value
Age (per 1 y)	1.04	1.03-1.05	0.001
Man vs woman	1.77	1.44-2.18	0.001
Physically active vs sedentary	0.63	0.51-0.78	0.001
Current smoker vs nonsmoker	1.12	1.01-1.24	0.075
Component 1: Fish, vegetables, legumes, cereals, and fruits	0.87	0.79-0.97	0.013
Component 2: Potatoes, red or white meat, and meat products.	1.13	1.05-1.21	0.004
Component 3: Bread, pasta	0.97	0.87-1.08	0.564
Component 4: Dairy products and eggs	1.04	0.93-1.15	0.516
Component 5: Sweets	1.06	0.96-1.18	0.268
Component 6: Alcoholic beverages	1.26	1.21-1.33	0.001

[a]Potential confounders also included in all analyses were smoking, years of school, income, use of medication, and body mass index.

technique (ie, the principal components analysis) it was found that six components might characterize the dietary habits of the participants. The healthful dietary pattern (component 1) has also been described in several other studies (21-26) and it is similar to the prudent pattern, which is high in vegetables, fruit, legumes, cereals, and fish. For example, Fung and colleagues (23), studying 71,768 women aged 38 to 63 years without a history of cardiovascular disease or diabetes, revealed a prudent dietary pattern that was characterized by higher intakes of fruits, vegetables, legumes, fish, and whole grains. Similarly, Schulz and colleagues (23), studying 24,958 middle-aged men and women from Potsdam, derived a food pattern that was characterized by high consumption of whole-grain bread, fruits and juices, grain flakes, cereals, and raw vegetables. Bamia and colleagues (24), using information from the European Prospective Investigation into Cancer and Nutrition study, revealed a vegetable-based dietary pattern that was also associated with younger age, a higher level of education, physical activity, lower waist-to-hip ratio, and never and past smoking. Costacou and colleagues (26), studying 28,034 participants of the Greek branch of the European Prospective Investigation into Cancer and Nutrition study, observed that the first principal component resembled the Mediterranean dietary pattern, which is similar to the pattern observed in our analysis. In all previous studies this healthful pattern was characterized by reduced risk of chronic diseases or markers associated with this risk. In our work, the first food pattern explained about 20% of the total variation in intake, and it was more likely to be adopted by younger people who did not smoke cigarettes and were involved in physical activities. In other words, these people seem to adopt a more healthful lifestyle. Despite these associations the dietary pattern that was described by the first, and most dominant, component was associated with a favorable effect on the characteristics of the metabolic syndrome. In particular, this pattern was inversely associated with waist circumference, systolic blood pressure, and triglyceride level, and positively associated with HDL-cholesterol levels (Table 3). In addition, this dietary pattern was associated with 13% lower likelihood of having the metabolic syndrome.

During the past decade a large body of evidence related adherence to a dietary pattern that is rich in fruits, legumes, vegetables, nonrefined cereals, and fish, with decreased all-cause mortality, as well as decreased incidence of coronary heart disease and various types of cancer (27-29). A potential explanation of the beneficial effect of this dietary pattern on the health of human beings could be attributed to the low saturated fat concentration, and to the high intake of monounsaturated fat, complex carbohydrates (from legumes), and fiber (from vegetables and fruits). The high content of vegetables, fresh fruits, cereals, and olive oil, is associated with a high intake of beta carotene, vitamins C and E, polyphenols, and various important minerals. These key elements have been suggested to be responsible for the beneficial effect of diet on the health of human beings (8,9,11,30-32). Many researchers relate this dietary pattern with improvements in blood lipid profiles (especially low-density lipoprotein cholesterol and triglyceride levels), decreased risk of thrombosis, improvement in endothelial function and insulin resistance, reduction in inflammation markers concentrations, and decrease in ventricular irritability (30-33).

Component 2 was mainly characterized by consumption of meat and meat products. This component explained the 12% of variance in intake and it was associated with higher waist circumference and lower HDL cholesterol levels. Meat intake has been implicated as a cardiovascular risk factor in several ways. In particular, about half of the fat from meat is saturated, which may raise serum cholesterol levels; meat provides arachidonic acid, a precursor of proinflammatory eicosanoids, which increase platelet aggregation propensity; and meat provides heme iron, which has been shown to promote oxidation of low-density lipoprotein cholesterol in vitro (34-37). A separate dietary pattern, mainly characterized by dairy products intake (component 4) was also observed. This pattern was positively associated only with triglyceride levels (Table 3). Dairy products (full fat) and especially milk have been associated in some studies as a potential promoter of cardiovascular disease because they are sources of cholesterol and saturated fatty acids (38,39). Alcohol intake characterized component 6, which was unfavorably associated with all the components of the metabolic syndrome and increased the likelihood of having the metabolic syndrome by 26%. The association of alcohol intake on anthropometric indexes, blood pressure, and lipid levels has already been reported in the literature (40-42). Although alcohol intake seems to protect life in human beings in moderate quantities, increased intake plays an adverse role in the risk of having metabolic disorders.

Our study has several limitations. As a cross-sectional investigation, it is not appropriate for cause–effect relationships. The sample consisted of only Greek people, and presents limitations regarding extrapolation to other ethnic populations. Because fat sources were excluded from the analyses due to methodologic problems in quantification, this may limit the strength of the findings. Moreover, the data analyses were not adjusted for the role of genetics due to lack of relevant information. Thus, the incomplete analysis may modify the relation between dietary patterns and the likelihood of having metabolic disorders. The principal components method itself also has some limitations that stem from several subjective decisions that have to be made in deciding the nature of the components that have been extracted (43).

CONCLUSIONS

In nutritional epidemiology, interest has shifted from the study of single nutrients or foods to the study of food groups and, more recently, dietary patterns. In this context, dietary habits of approximately 3,000 healthy Greek men and women were analyzed and several food patterns were revealed. There are not many studies that have examined the relationship between food patterns derived using PCA and indexes of the metabolic syndrome. The food patterns derived in our work explained 56% of the variance in dietary intake and suggest that a pattern rich in cereals, fish, legumes, vegetables, and fruits is strongly associated with reduced levels of clinical and biological markers linked to the metabolic syndrome, whereas meat, potatoes, and alcohol intake showed opposite results. A better understanding of the relationships between food intake and metabolic characteristics of people may help in the prevention of the upcoming epidemic of the metabolic syndrome. Future intervention trials may confirm or refute the findings presented here.

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