ORIGINAL

Associations of dietary patterns with metabolic syndrome and insulin resistance : a cross-sectional study in a Japanese population

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Abstract : The associations of dietary patterns with metabolic syndrome (MetS) and insulin resistance have not been fully investigated in the Japanese population. A cross-sectional study was performed on 513 subjects without treatment for diabetes who had participated in the baseline survey of a cohort study in Tokushima Prefecture, Japan. Frequencies of consumption of 46 foods and beverages were assessed using a questionnaire. MetS was diagnosed using the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria. Logistic and linear regression analyses were used to examine the associations of the dietary patterns with the prevalence of MetS, its components, and the Homeostasis Model of Assessment-Insulin Resistance (HOMA-IR). Using principal component analysis, four dietary patterns were extracted : prudent diet (high intake of vegetables and fruits) ; high fat/Western (high intake of fried foods, fried dishes and meat) ; bread and dairy products ; and seafood patterns. After adjustment for sex, age, and other potential confounders, prudent diet pattern scores were inversely correlated with the prevalence of reduced serum high-density lipoprotein cholesterol ($P=0.04$) and high blood pressure ($P=0.05$), and bread and dairy products pattern scores were correlated with a lower prevalence of abdominal obesity ($P=0.04$) and high plasma glucose ($P=0.04$). The high fat/Western pattern was positively correlated with HOMA-IR ($P=0.04$). Prudent dietary pattern and bread and dairy products pattern may be correlated with a lower prevalence of some components of MetS. A high fat/Western dietary pattern may be positively associated with insulin resistance in the Japanese population. J. Med. Invest. 61 : 333-344, August, 2014

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INTRODUCTION

Recently, obesity and related disorders have become major health problems in not only Western, but also Asian countries. Metabolic syndrome (MetS) is defined as a cluster of central obesity, impaired glucose tolerance, dyslipidemia (elevated triglyceride levels, reduced high-density lipoprotein [HDL] cholesterol levels), and high blood pressure, with abnormal fat distribution and insulin resistance playing major roles in the etiology of the syndrome (1-3). People with MetS are reported to be at high risk for cardiovascular disease (4) and type 2 diabetes (5). According to the National Nutritional and Health Survey data collected in 2008, the prevalence of MetS was estimated at 25.3% for men and 10.6%

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for women in Japan (6). As a preventive measure, the Japanese Ministry of Health and Welfare introduced a health-check-up and a health education program targeted at MetS for adults aged 40-74 years, who have various kinds of health insurance, in April 2008.

Dietary habits may play a crucial role in the development of MetS and insulin resistance. Previous epidemiologic studies performed in Iran (7) and the U.S. (8) reported that a healthy/prudent dietary pattern rich in vegetables and fruits was associated with a lower prevalence of MetS. On the other hand, a Western diet pattern rich in high fat foods was associated with a higher incidence rate or prevalence of MetS (7, 9, 10). With regard to food items or food groups, meat, fried foods and soft drinks were reported to be risk factors for MetS in the U.S. (9, 11), while dairy products were suggested to be a protective factor (9, 12). In cross-sectional studies on insulin resistance, a healthy/prudent dietary pattern was reported to be inversely correlated (7, 13, 14), whereas a Western diet pattern was positively correlated with the Homeostasis Model of Assessment-Insulin Resistance (HOMA-IR) or serum levels of insulin (7, 13). A recent study in Japan reported that a diet characterized by high intake of bread, Western-type and Japanese confectioneries, and milk and yogurt, and low intake of rice was inversely correlated with HOMA2-IR, a modified version of HOMA-IR (15).

The associations between dietary patterns and MetS and insulin resistance have not been fully investigated in Asian countries, including Japan (15-18). It is unclear whether the results of epidemiologic studies are directly applicable to other countries or populations in which the dietary habits and nutritional intake greatly differ. A few prospective studies have investigated the association between dietary patterns and cardiovascular disease mortality (19) and type 2 diabetes (20) in Japan. However, it may be still of value to examine the factors associated with MetS, an intermediate outcome variable of cardiovascular disease and diabetes. In the present report, we examined the correlation between the dietary patterns and prevalence of MetS, its components and insulin resistance in Japan.

METHODS

Study subjects

The present study population comprised 577 men and women 35-70 years of age, who attended the Tokushima Prefectural General Health Checkup Center, and joined in the baseline survey of the Japan Multi-Institutional Collaborative Cohort (J-MICC) Study, from January 23, 2008 to November 24, 2011. Of 3,911 subjects who had a medical check-up during the study period and were asked to take part in the J-MICC Study, 577 (14.8%) agreed. In this health check-up center, examinees mainly consist of persons who voluntarily receive a multiphasic health check-up, laborers who receive a periodical health check-up based on the Industrial Safety and Health Law, and general inhabitants who are covered by the national health insurance and receive an annual health examination. Subjects who had a previous history of stroke (N=5) or ischemic heart disease (N=8), who were under treatment for diabetes (N=35), or whose data on the health check-up (N=10) or at least one item of dietary habit were missing (N=6), were excluded, and the data from the remaining 513 subjects (377 men and 136 women) were analyzed in the present study. The details of the J-MICC Study have been described in another report (21). After explaining the outline and objective of the study in detail, written informed consent was obtained from each participant. The study protocol was approved by the institutional review boards of Nagoya University School of Medicine (the affiliation of the former principal investigator, Dr. N. Hamajima), Aichi Cancer Center (the affiliation of the present principal investigator, Dr. H. Tanaka), and Tokushima University Hospital.

Questionnaires

Each participant was asked to answer a self-administered questionnaire that inquired about current and previous diseases, physical activity, dietary habits, and smoking and drinking habits. Regarding dietary habits, subjects were asked how often they had consumed 46 food and beverage items over the past year. The frequency of intake of staple foods (rice, bread, and noodles) at breakfast, lunch, and supper was divided into seven categories : rarely ; 1-3 times/month ; 1-2 times/week ; 3-4 times/week ; 5-6 times/week ; and every day. The amount of staple foods consumed at each meal was also confirmed (how many cups, or slices or rolls/meals). The amounts of rice, bread and noodles consumed/week were calculated by summing the product of the frequency of intake and the amount consumed at each meal. For the other 43 foods and beverages, the frequency of intake was divided into eight categories : rarely ; 1-3 times/month ; 1-2 times/week ; 3-4 times/week ; 5-6 times/week ; 1 time/day ; 2 times/day ; and ≥ 3 times/day. The total energy intake was calculated using a program developed at the Department of Public Health, Nagoya City University School of Medicine. The validity and the reproducibility of the food frequency questionnaire have been published by Tokudome *et al.* (22) and Imaeda *et al.* (23), respectively. Physical activity during leisure time was estimated by multiplying the frequency and duration of light (walking, hiking, etc., 3.4 metabolic equivalents [METs]), moderate (light jogging, swimming, etc., 7.0 METs), and heavy exercise (marathon, combative sports, etc., 10.0 METs) and summed, and expressed as METs-hours/week.

Diagnosis of MetS and measurement of insulin resistance

Data on anthropometric measurements (height, weight, and waist circumference), blood pressure, fasting plasma glucose, and serum levels of triglycerides and HDL-cholesterol were obtained at the time of routine medical checkups. Subjects were requested not to eat after 20 : 00 PM, and received a medical checkup from 8 : 00 to 11 : 30 AM the next day. Blood pressure was measured in a sitting position, using a mercury sphygmomanometer. If a measurement was far from the study subject's usual values, blood pressure was repeatedly measured and the measurement closer to their usual values was adopted. Waist circumference was measured with a cloth tape at the umbilicus. For 24 subjects whose data on waist circumference were missing, self-reported data from the questionnaire were used instead. Serum levels of insulin were measured by Chemiluminescence Immunoassay at BML Inc. (Tokyo, Japan).

The diagnosis of MetS was performed using the NCEP ATP III criteria (1, 2), with some modifications. Subjects were diagnosed as having MetS when they fulfilled at least three of the following five conditions : waist circumference ≥ 90 cm in men or ≥ 80 cm in women (recommended cut-off points for Asians) ; serum triglycerides ≥ 150 mg/dl ; HDL-cholesterol < 40 mg/dl in men or < 50 mg/dl in women ; systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg or under treatment for hypertension ; and fasting plasma glucose ≥ 100 mg/dl. To assess the robustness of the results, analysis was repeated using the criteria of JASSO (3). In the JASSO criteria, subjects were diagnosed as having MetS when they had a waist circumference ≥ 85 cm in men or ≥ 90 cm in women and at least two of the following three criteria : serum triglycerides ≥ 150 mg/dl and/or HDL-cholesterol < 40 mg/dl ; systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg or under treatment for hypertension ; and fasting plasma glucose ≥ 110 mg/dl.

The HOMA-IR and Quantitative Insulin Sensitivity Check Index (QUICKI) were calculated using the following equations :

HOMA-IR=insulin (μU/ml) X plasma glucose (mg/dl)/405.

QUICKI=1/ ((log (insulin (μU/ml)) + log (plasma glucose (mg/dl))).

Statistical analysis

Comparison of the characteristics of the study subjects according to the presence/absence of MetS was performed using two-sample t-test, Wilcoxon rank-sum test, chi-square test or Fisher's exact test. Principal component analysis was performed to assess dietary patterns using a correlation matrix for 46 food items, without adjustment for total energy intake. The principal components were selected on the basis of eigenvalues (≥ 1.0) and interpretability. Principal component scores were saved for each individual, and their relationships with sex, age, smoking and drinking habits, leisure-time physical activity, and total energy intake were examined using a two-sample t-test or analysis of variance. The association between each dietary pattern score (continuous variable) with the prevalence of MetS, its components, HOMA-IR, and QUICKI were investigated using logistic and linear regression analyses. HOMA-IR was log-transformed before linear regression analysis, since its distribution was positively skewed. The covariates included in the models were sex, age (continuous), total energy intake (quartiles, three indicator variables), physical activity (quartiles), and smoking (current, no, and past smokers) and drinking habits (current drinkers and others). To assess whether the correlations between dietary patterns and HOMA-IR or QUICKI were intermediated by obesity, an analysis additionally adjusting for body mass index (BMI, continuous) was also performed. In addition, on the basis of the analysis of dietary patterns, linear regression analysis was performed to assess which food items were significantly correlated with HOMA-IR. Odds ratios (OR) and their profile likelihood 95% confidence intervals (CI), and partial regression coefficients and their 95% CI, associated with an increase of 1 S.D. of each principal component score, or 1 cup, slice or time/week of each food item, were calculated. A likelihood-ratio test was used to compute P-values in logistic regression analysis. P-values < 0.05 in two-tailed tests were considered to be significant. All statistical analyses were performed using the PRINCOMP, TTEST, ANOVA, LOGISTIC, and REG procedures of the SAS software package (version 8.2) (24).

RESULTS

Table 1 shows descriptive data on age, anthropometric measurements, blood pressure, blood biochemical tests, HOMA-IR, QUICKI, total energy intake, physical activity, and the proportion of men, smokers, and drinkers, according to the presence/absence of MetS (NCEP ATP III criteria). The overall prevalence of MetS was 91/513 (17.7%). The mean age was somewhat older (P=0.05), and the proportion of current smoker was somewhat higher (P=0.08), among those who had MetS than those who did not have MetS.

In principal component analysis, four dietary patterns were identified, and these four principal components explained 33% of the total variance. Table 2 shows the factor loadings ; i.e., the correlation coefficients between scores of each principal component and the frequency of intake of foods and beverages. The first principal component was labeled the prudent diet pattern because of the high factor loadings for vegetables, fruits, and mushrooms. The second principal component was labeled the high

Table 1. Characteristics of the study population according to the presence of metabolic syndrome (MetS, NCEP ATP III criteria)

	MetS - (No.=422)	MetS + (No.=91)	P-value
Age (years)[a]	51.4 (9.4)	53.5 (8.9)	0.05
Height (cm)[a]	166.0 (7.6)	165.9 (9.6)	0.89
Weight (kg)[a]	63.7 (10.3)	73.7 (14.2)	< 0.0001
Body mass index (kg/m^2)[a]	23.0 (2.8)	26.6 (3.5)	< 0.0001
Waist circumference (cm)[a]	82.2 (8.2)	92.1 (9.3)	< 0.0001
Systolic blood pressure (mmHg)[a]	115.5 (13.2)	129.8 (14.4)	< 0.0001
Diastolic blood pressure (mmHg)[a]	70.5 (9.9)	79.4 (11.9)	< 0.0001
Triglycerides (mg/dl)[b]	85 (64, 117)	169 (121, 225)	< 0.0001
High-density lipoprotein cholesterol (mg/dl)[a]	61.2 (16.0)	48.2 (17.2)	< 0.0001
Fasting plasma glucose (mg/dl)[b]	95 (90, 101)	104 (96, 112)	< 0.0001
Insulin (μU/ml)[b]	5.0 (3.6, 7.0)	9.6 (6.8, 14)	< 0.0001
HOMA-IR[b]	1.17 (0.84, 1.67)	2.43 (1.76, 4.00)	< 0.0001
QUICKI[a]	0.16 (0.01)	0.14 (0.01)	< 0.0001
Total energy intake (kcal/day)[a]	1796 (330)	1826 (371)	0.45
Physical activity (METs-hours/week)[b]	6.3 (1.2, 18.4)	5.0 (0.40, 20.4)	0.32
Sex (No., %)[c]			
Men	309 (73.2)	68 (74.7)	0.77
Women	113 (26.8)	23 (25.3)	
Smoking habit (No., %)[c]			
Current	91 (21.6)	27 (29.7)	0.08
Past	136 (32.2)	33 (36.3)	
No	195 (46.2)	31 (34.1)	
Drinking habit (No., %)[c]			
Current	274 (64.9)	63 (69.2)	0.73
Past	8 (1.9)	1 (1.1)	
No	140 (33.2)	27 (29.7)	

[a] Mean (S.D.). Comparison was based on two-sample t-test.

[b] Median (25%, 75%). Comparison was based on Wilcoxon rank-sum test.

[c] Comparison was based on chi-square test or Fisher's exact test.

Table 2. Factor loading matrix for major dietary patterns

	Dietary pattern			
	Prudent	High fat/Western	Bread and dairy products	Seafood
Rice	-	-0.23	-0.47	-
Bread	-	0.25	0.62	-
Noodles	-	0.24	-	-
Margarine	-	-	0.52	-
Butter	-	-	-	0.28
Milk	0.23[a]	-	0.37	-
Yogurt	-	-	0.46	-
Miso soup	0.29	-0.38	-0.32	-
Bean curd	0.22	-	-	-
Soybeans, fermented soybeans	0.43	-0.35	-	-
Eggs	0.30	0.39	-	-
Chicken	0.29	0.46	-	-
Beef, pork	0.40	0.46	-	-
Liver	-	-	-0.24	0.49
Ham, sausage, salami, bacon	0.29	0.46	-	-
Fish (raw, boiled, grilled)	0.48	-	-	0.36
Small fish with bones	0.46	-0.40	-	0.20
Canned tuna	0.24	0.28	-	-
Squid, shrimp, crab, octpus	0.21	0.21	-	0.44
Shellfish (cram, oyster)	0.27	-	-0.31	0.52
Salted cod roe, salmon roe	-	0.29	-0.23	0.55
Tube-shaped fish paste cake, boiled fish paste	0.30	-	-	-
Deep-fried bean curd	0.50	-	-	-
Potato, taro, sweet potato	0.63	-	0.24	-
Pumpkin	0.52	-	-	-
Carrot	0.69	-	0.22	-
Broccoli	0.52	-	-	-
Green leafy vegetables (spinach, komatsuna, garland chrysanthemum)	0.67	-	-	-
Other green and yellow vegetables (bell peppers, string beans)	0.66	-	-	-0.21
Cabbage	0.65	-	-	-0.23
Japanese white radish	0.66	-	-	-
Kiriboshi-daikon	0.37	-	-0.20	-
Burdock, bamboo shoot	0.56	-	-	-
Other vegetables (cucumber, onion, bean sprouts, Chinese cabbage, lettuce)	0.68	-	-	-0.28
Mushrooms	0.68	-	-	-
Seaweed	0.53	-	-	-
Mayonnaise	0.28	0.47	-0.23	-
Fried foods	0.30	0.57	-	-0.22
Fried dishes	0.49	0.47	-	-0.27
Mandarin orange, orange, grapefruit	0.55	-	0.20	-
Other fruits (strawberry, kiwi, apple, water melon)	0.53	-	0.28	-
Peanuts, almond	0.26	-	-	0.20
Western-style confectionery	-	0.41	0.21	-
Japanese confectionery	0.28	-	-	0.31
Green tea	0.30	-0.25	-	-
Coffee	-	-	-	-
Eigen value	7.91	2.93	2.29	2.12
Cumulative (%)	17	24	29	33

[a] For simplicity, only factor loadings with ≤-0.20 or 0.20≤ are shown in the table.

fat/Western dietary pattern because of the high loadings for meat, meat products, mayonnaise, fried foods, fried dishes, and western-style confectionery. The third component was labeled the bread and dairy products pattern, because the factor loading was high for bread, margarine, milk, and yogurt. The fourth principal component was named the seafood pattern because of the high loadings for squid, shrimp, crab, octopus, shellfish, and roe. There were nine other principal components with eigenvalues ≥ 1.0. However, the interpretation of these components was difficult.

Table 3 shows the mean principal component scores in relation to sex, age, and lifestyle factors. Men had lower mean principal component scores of prudent diet and bread and dairy products patterns than women. Age was positively correlated with prudent and seafood pattern scores, while it was negatively correlated with high fat/Western dietary pattern scores. Current smokers and current drinkers had lower scores of prudent and bread and dairy products patterns than the remaining groups. Physical activity at leisure time was positively correlated with a prudent dietary pattern, and negatively correlated with a high fat/Western dietary pattern. Total energy intake was inversely correlated with bread

Table 3. Mean principal component scores in relation to sex, age, smoking and drinking habits, physical activity, and total energy intake

	Prudent		High fat/Western		Bread and dairy		Seafood	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sex								
Men	-0.47	2.37	0.04	1.67	-0.26	1.41	0.03	1.49
Women	1.31	3.46	-0.12	1.82	0.72	1.55	-0.07	1.36
P-value[a]	< 0.0001		0.36		< 0.0001		0.51	
Age (years)								
35-39	-0.22	2.50	0.93	1.41	-0.15	1.35	-0.53	1.23
40-49	-0.62	2.18	0.70	1.59	0.08	1.46	-0.31	1.18
50-59	0.18	2.67	0.00	1.52	-0.13	1.64	0.07	1.27
60-70	0.54	3.53	-1.19	1.54	0.17	1.46	0.49	1.85
P-value[b]	0.004		< 0.0001		0.26		< 0.0001	
Smoking								
Current	-0.86	2.13	0.32	1.60	-0.51	1.57	0.09	1.95
Past	-0.18	2.53	-0.10	1.67	-0.11	1.52	0.06	1.29
No	0.58	3.18	-0.09	1.79	0.35	1.39	-0.09	1.27
P-value[b]	< 0.0001		0.07		< 0.0001		0.44	
Drinking								
Current	-0.26	2.50	0.08	1.60	-0.18	1.47	0.05	1.50
Others	0.50	3.27	-0.16	1.91	0.34	1.54	-0.10	1.37
P-value[a]	0.007		0.14		0.0002		0.24	
Physical activity (METs-hours/week)								
< 1.2	-0.60	2.52	0.54	1.68	-0.05	1.65	-0.14	1.40
≥ 1.2 and < 6.2	-0.15	3.06	0.00	1.58	-0.09	1.42	-0.12	1.73
≥ 6.2 and < 18.4	0.39	2.89	-0.35	1.67	-0.01	1.45	0.17	1.34
≥ 18.4	0.29	2.64	-0.12	1.83	0.17	1.58	0.08	1.28
P-value[b]	0.03		0.0009		0.52		0.26	
Total energy intake (kcal/day)								
< 1570	-0.55	2.21	-0.15	1.39	0.43	1.39	-0.01	1.69
≥ 1570 and < 1799	0.03	2.67	-0.04	1.59	0.24	1.38	-0.02	1.20
≥ 1799 and < 1980	0.41	3.53	-0.12	1.96	-0.04	1.53	-0.03	1.41
≥ 1980	0.10	2.62	0.30	1.83	-0.62	1.55	0.06	1.50
P-value[b]	0.05		0.12		< 0.0001		0.96	

[a] by two-sample t-test.
[b] by analysis of variance.

and dairy products pattern scores.

Table 4 presents the results on the sex- and age-adjusted and multivariate adjusted associations of dietary patterns with the prevalence of MetS and its components diagnosed using the criteria of NCEP ATP III. After adjustment for sex, age, total energy intake, physical activity, and smoking and drinking habits, prudent diet pattern scores were inversely correlated with the prevalence of low serum HDL cholesterol (P=0.04) and high blood pressure (P=0.05). Bread and dairy products pattern scores were correlated with significantly lower prevalence of abdominal obesity (P=0.04) and high plasma glucose (P=0.04).

The associations of dietary pattern scores with the prevalence of MetS and its components were also

Table 4. Associations of dietary patterns with the prevalence of metabolic syndrome and its components (NCEP ATP III criteria), and insulin resistance

	Dietary pattern											
	Prudent			High fat/Western			Bread and dairy products			Seafood		
Logistic regression	OR	(95% CI)	*P*-value	OR	(95% CI)	*P*-value	OR	(95% CI)	*P*-value	OR	(95% CI)	*P*-value
Metabolic syndrome (No. of cases/subjects=91/513)												
Model 1[a]	0.73	(0.54 - 0.95)	0.02	1.14	(0.89 - 1.47)	0.30	0.82	(0.65 - 1.04)	0.11	1.15	(0.92 - 1.44)	0.20
Model 2[b]	0.77	(0.56 - 1.03)	0.07	1.08	(0.83 - 1.42)	0.56	0.89	(0.69 - 1.14)	0.34	1.14	(0.91 - 1.44)	0.24
Waist circumference ≥ 90 cm in men and ≥ 80 cm in women (No. of cases/subjects=182/513)												
Model 1[a]	0.82	(0.66 - 1.00)	0.05	1.19	(0.97 - 1.47)	0.10	0.80	(0.66 - 0.97)	0.03	1.02	(0.84 - 1.24)	0.81
Model 2[b]	0.85	(0.68 - 1.05)	0.13	1.20	(0.97 - 1.49)	0.10	0.81	(0.66 - 1.00)	0.04	1.03	(0.85 - 1.25)	0.75
Triglycerides ≥ 150 mg/dl (No. of cases/subjects=113/513)												
Model 1[a]	0.83	(0.64 - 1.07)	0.15	1.14	(0.90 - 1.44)	0.28	0.80	(0.64 - 1.00)	0.05	1.16	(0.94 - 1.43)	0.17
Model 2[b]	0.91	(0.69 - 1.18)	0.51	1.14	(0.89 - 1.46)	0.29	0.82	(0.64 - 1.04)	0.10	1.17	(0.95 - 1.47)	0.15
High-density lipoprotein cholesterol < 40 mg/dl in men and < 50 mg/dl in women (No. of cases/subjects=65/513)												
Model 1[a]	0.66	(0.46 - 0.92)	0.01	1.05	(0.78 - 1.40)	0.75	1.01	(0.77 - 1.32)	0.96	0.99	(0.75 - 1.28)	0.96
Model 2[b]	0.69	(0.47 - 0.99)	0.04	0.99	(0.72 - 1.34)	0.94	1.05	(0.79 - 1.39)	0.75	0.99	(0.75 - 1.27)	0.93
Systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg or treated for hypertension (No. of cases/subjects=151/513)												
Model 1[a]	0.83	(0.66 - 1.02)	0.08	1.07	(0.85 - 1.34)	0.55	0.87	(0.71 - 1.07)	0.19	1.07	(0.88 - 1.31)	0.49
Model 2[b]	0.79	(0.61 - 1.00)	0.05	1.04	(0.81 - 1.32)	0.77	0.89	(0.71 - 1.11)	0.31	1.07	(0.87 - 1.31)	0.53
Fasting plasma glucose ≥ 100 mg/dl (No. of cases/subjects=186/513)												
Model 1[a]	0.81	(0.65 - 1.00)	0.05	0.88	(0.71 - 1.09)	0.25	0.80	(0.66 - 0.98)	0.03	1.05	(0.86 - 1.27)	0.65
Model 2[b]	0.84	(0.66 - 1.05)	0.13	0.84	(0.67 - 1.06)	0.15	0.80	(0.65 - 1.00)	0.04	1.02	(0.83 - 1.25)	0.87
Linear regression	β	(95% CI)	*P*-value	β	(95% CI)	*P*-value	β	(95% CI)	*P*-value	β	(95% CI)	*P*-value
log (HOMA-IR)												
Model 1[c]	-0.042	(-0.097 - 0.013)	0.13	0.070	(0.012 - 0.129)	0.02	-0.052	(-0.107 - 0.002)	0.06	0.020	(-0.034 - 0.074)	0.47
Model 2[d]	-0.045	(-0.104 - 0.014)	0.13	0.063	(0.002 - 0.123)	0.04	-0.052	(-0.109 - 0.004)	0.07	0.025	(-0.029 - 0.080)	0.36
Model 3[e]	-0.026	(-0.074 - 0.022)	0.29	0.045	(-0.004 - 0.094)	0.07	-0.013	(-0.059 - 0.033)	0.57	0.032	(-0.013 - 0.076)	0.16
QUICKI												
Model 1[c]	0.0011	(-0.0003 - 0.0025)	0.12	-0.0018	(-0.0033 - -0.0003)	0.02	0.0012	(-0.0002 - 0.0026)	0.08	-0.0005	(-0.0018 - 0.0009)	0.47
Model 2[d]	0.0012	(-0.0003 - 0.0027)	0.11	-0.0016	(-0.0031 - -0.0001)	0.04	0.0012	(-0.0003 - 0.0026)	0.11	-0.0006	(-0.0020 - 0.0007)	0.37
Model 3[e]	0.0007	(-0.0005 - 0.0020)	0.23	-0.0012	(-0.0024 - 0.0001)	0.06	0.0002	(-0.0010 - 0.0014)	0.73	-0.0008	(-0.0019 - 0.0004)	0.18

[a] Odds ratios associated with an increase in 1 S.D. of the principal component score, adjusted for age and sex.

[b] Odds ratios associated with an increase in 1 S.D. of the principal component score, adjusted for age, sex, total energy intake, physical activity, and smoking and drinking habits.

[c] Partial regression coefficient associated with an increase in 1 S.D. of the principal component score, adjusted for age and sex.

[d] Partial regression coefficient associated with an increase in 1 S.D. of the principal component score, adjusted for age, sex, total energy intake, physical activity, and smoking and drinking habits.

[e] Partial regression coefficient associated with an increase in 1 S.D. of the principal component score, adjusted for age, sex, total energy intake, physical activity, smoking and drinking habits, and BMI.

examined using the criteria of JASSO (Table 5). The prevalence of MetS by this definition was 57/513 (11.1%). Overall, the direction and magnitude of the associations of dietary patterns with MetS and its components did not greatly differ. However, the high fat/Western diet pattern scores were positively correlated with the prevalence of high waist circumference (OR=1.29, 95% CI 1.03-1.61, *P*=0.03).

After adjustment for sex, age, total energy intake, physical activity, and smoking and drinking habits, high fat/Western pattern scores were positively and significantly correlated with HOMA-IR (*P*=0.04) (Table 4). The inverse association between bread and dairy products pattern and HOMA-IR was marginally significant (*P*=0.07). When BMI was further adjusted, the positive correlation between high fat/Western pattern scores and HOMA-IR was marginally significant (*P*=0.07). When QUICKI was used as an independent variable, the results were essentially the same (Table 4).

Finally, multiple linear regression analysis was repeated to assess more precisely which food items of the high fat/Western pattern were correlated with HOMA-IR. In this analysis, food items which showed correlation coefficients of ≤-0.35 or 0.35≤ with high fat/Western pattern scores were examined, after adjustment for sex, age, total energy intake, physical activity, and smoking and drinking habits. Correlations of the intake frequency of small fish with bones (partial regression coefficient=-0.0294, 95% CI -0.0604 - 0.0016, *P*=0.06) and mayonnaise (partial regression coefficient=0.0264, 95% CI -0.0009 - 0.0537, *P*=0.06) with HOMA-IR were marginally significant. However, none of the other food items of the high fat/Western pattern was significantly correlated with HOMA-IR.

DISCUSSION

In the present study, principal component analysis was used to examine dietary patterns. Principal component analysis transforms a large number of mutually correlated variables to a smaller number of uncorrelated variables, while maintaining the variability of the original data as much as possible. It is

Table 5. Associations of dietary patterns with the prevalence of metabolic syndrome and its components (JASSO criteria)

	Dietary pattern											
	Prudent			High fat/Western			Bread and dairy products			Seafood		
Logistic regression	OR	(95% CI)	*P*-value	OR	(95% CI)	*P*-value	OR	(95% CI)	*P*-value	OR	(95% CI)	*P*-value
Metabolic syndrome (No. of cases/subjects=57/513)												
Model 1[a]	0.79	(0.54 - 1.10)	0.17	1.33	(0.98 - 1.82)	0.07	0.91	(0.67 - 1.22)	0.51	1.16	(0.89 - 1.50)	0.25
Model 2[b]	0.79	(0.53 - 1.12)	0.20	1.31	(0.94 - 1.80)	0.11	0.99	(0.73 - 1.34)	0.96	1.19	(0.91 - 1.53)	0.20
Waist circumference ≥ 85 cm in men and ≥ 90 cm in women (No. of cases/subjects=211/513)												
Model 1[a]	0.82	(0.66 - 1.02)	0.08	1.34	(1.08 - 1.67)	0.01	0.78	(0.63 - 0.96)	0.02	1.08	(0.89 - 1.32)	0.44
Model 2[b]	0.80	(0.63 - 1.01)	0.06	1.29	(1.03 - 1.61)	0.03	0.82	(0.66 - 1.01)	0.07	1.10	(0.90 - 1.35)	0.36
Triglycerides ≥ 150 mg/dl or high desity lipoprotein chlesterol < 40 mg/dl (No. of cases/subjects=133/513)												
Model 1[a]	0.81	(0.63 - 1.02)	0.07	1.11	(0.89 - 1.40)	0.35	0.87	(0.71 - 1.08)	0.21	1.15	(0.94 - 1.41)	0.19
Model 2[b]	0.87	(0.67 - 1.11)	0.27	1.13	(0.89 - 1.42)	0.33	0.89	(0.71 - 1.11)	0.29	1.16	(0.95 - 1.45)	0.15
High-density lipoprotein cholesterol < 40 mg/dl (No. of cases/subjects=53/513)												
Model 1[a]	0.68	(0.45 - 0.98)	0.04	1.04	(0.75 - 1.43)	0.82	0.99	(0.73 - 1.34)	0.93	0.99	(0.72 - 1.30)	0.95
Model 2[b]	0.71	(0.46 - 1.06)	0.10	0.97	(0.69 - 1.36)	0.86	1.04	(0.76 - 1.42)	0.82	0.98	(0.73 - 1.29)	0.91
Systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg or treated for hypertension (No. of cases/subjects=151/513)												
Model 1[a]	0.83	(0.66 - 1.02)	0.08	1.07	(0.85 - 1.34)	0.55	0.87	(0.71 - 1.07)	0.19	1.07	(0.88 - 1.31)	0.49
Model 2[b]	0.79	(0.61 - 1.00)	0.05	1.04	(0.81 - 1.32)	0.77	0.89	(0.71 - 1.11)	0.31	1.07	(0.87 - 1.31)	0.53
Fasting plasma glucose ≥ 110 mg/dl (No. of cases/subjects=54/513)												
Model 1[a]	0.87	(0.61 - 1.19)	0.40	0.87	(0.63 - 1.21)	0.42	0.79	(0.58 - 1.07)	0.12	1.20	(0.92 - 1.55)	0.17
Model 2[b]	0.89	(0.61 - 1.24)	0.51	0.85	(0.60 - 1.19)	0.35	0.77	(0.55 - 1.05)	0.10	1.19	(0.91 - 1.54)	0.20

[a] Odds ratio associated with an increase in 1 S.D. of the principal component score, adjusted for age and sex.

[b] Odds ratio associated with an increase in 1 S.D. of the principal component score, adjusted for age, sex, total energy intake, physical activity, and smoking and drinking habits.

also an effective way to cope with the problem of collinearity (25). This approach differs from those that hypothesize an ideal dietary pattern, or extract dietary patterns closely correlated with the intake of nutrients selected as risk or protective factors of a disease, such as reduced rank regression (26). We identified four dietary patterns, i.e., prudent diet, high fat/Western diet, bread and dairy products, and seafood patterns. Prudent/healthy diet and high fat/Western diet patterns have been consistently identified in previous studies performed in various countries, including Japan (19, 20, 27, 28), Korea (17), Iran (7), and the U.S. (8, 9, 13). The bread and dairy products pattern was analogous to the Westernized breakfast pattern reported by Akter *et al.* (15, 16) except for the lower factor loadings for Western-type and Japanese confectioneries, and the bread pattern reported from another study group of the J-MICC study (27), except for somewhat higher factor loadings for milk and yogurt, and a negative factor loading for shellfish. The seafood pattern identified in this study was similar to that reported by Nanri *et al.* (27), despite somewhat lower factor loadings for fish and small fish with bones, as well as that reported for another Japanese population by us (29) except for alcoholic beverages (which were not included in the present analysis of dietary patterns).

Prudent diet pattern scores were correlated with a lower prevalence of reduced serum HDL cholesterol and high blood pressure in our study. Inverse associations between the healthy/prudent diet patterns and MetS and its components have been observed in several, but not all, previous studies. In cross-sectional analyses, healthy/prudent dietary patterns, characterized by high intake of vegetables, fruits, whole grains, and legumes, were inversely correlated with the prevalence of MetS and all of its components in Iran (7), and MetS, central obesity, and serum triglycerides in the U.S. (8). On the other hand, the prudent diet pattern scores were not significantly associated with the incidence rate of MetS in the U.S. (9), or the prevalence of MetS or any of its components in Mexico (10). Vegetables and fruits may increase satiety and thus contribute to a lower risk of obesity (8). Soluble dietary fibers contained in these foods may also inhibit intestinal absorption of cholesterol and bile acids, which may lead to a better serum lipid profile (30). In addition, electrolytes abundantly contained in vegetables and fruits, such as potassium, may contribute to lower blood pressure (31). Finally, antioxidants contained in various fruits, vegetables, and legumes may have beneficial effects on the risk of MetS (32).

Bread and dairy products pattern scores were inversely correlated with the prevalence of abdominal obesity and high blood glucose (NCEP ATP III criteria). These results were in line with those of several studies performed in Western countries, despite some inconsistent results on each component of MetS. Intake of dairy products was negatively associated with a 10-year cumulative incidence of MetS, obesity, high blood glucose, and high blood pressure among those with BMI ≥ 25 kg/m^2 in the U.S. (12). Intake of dairy products was also inversely associated with the incidence rate of MetS in the U.S. (9) and France (33). In addition, dairy products, especially low-fat dairy foods, were associated with a reduced risk of developing type 2 diabetes in U.S. men (34). In recent cross-sectional studies of the Japanese population, a Westernized breakfast pattern, characterized by a high intake of bread, Western-type and Japanese confectionaries, milk and yogurt, and low intake of rice and alcohol, was correlated with a lower HOMA2-IR (15) and a lower prevalence of MetS (16). The suggested biological mechanisms linking dairy products and reduced risk of obesity, glucose intolerance, and type 2 diabetes include the effects of dietary calcium to increase fecal fat excretion, of 25-(OH)-cholecalciferol and intracellular calcium to increase insulin sensitivity through effects on adipocytes and skeletal muscle cells (35), and of milk protein and lactose to increase satiety and to reduce the risk of obesity (12). A recent prospective cohort study performed in Japan reported that intake of white rice was associated with an increased risk of diabetes in women (36). Therefore, another explanation of the results may be the negative correlation of this dietary pattern with consumption of rice ($r=-0.47$, Table 2). However, in analysis of each food item, consumption of rice was not significantly correlated with the prevalence of high blood glucose (data not shown), precluding the contribution of low rice intake.

High fat/Western diet pattern scores were positively correlated with the prevalence of high waist circumference (JASSO criteria). Many earlier studies showed positive associations between this dietary pattern and MetS. The Atherosclerosis Risk in Communities Study showed that Western diet pattern scores and frequency of intake of meat and fried foods were positively associated with the incidence rate of MetS (9). The Framingham Nutrition Study also showed that a diet high in total fat and cholesterol, and low in carbohydrate, dietary fiber, and vitamins, was associated with increased risks of MetS and abdominal obesity (37). It is well recognized that consumption of high-fat and energy-dense foods contributes to the development of obesity/overweight and related complications in the long term (8). The high fat/Western diet pattern scores were also significantly and positively correlated with HOMA-IR. This result was consistent with that of a study conducted in Iran (7). The marginally significant correlation even after adjustment for BMI suggests that the association between this dietary pattern and HOMA-IR was not totally confounded or mediated by obesity or being overweight. In an analysis of individual foods, frequency of intake of small fish with bones was negatively correlated with HOMA-IR ($P=0.06$). Lower intake of some foods rich in calcium and Vitamin D might at least in part explain the positive correlation between the high fat/Western dietary pattern and insulin resistance in our study population.

Several limitations of the present study should be addressed. First, because this was a cross-sectional study, the time sequence of exposure (dietary pattern) and outcome variables (MetS, its components and insulin resistance) are obscure. Second, dietary patterns extracted using principal component analysis may be specific to the study population, their interpretation may be subjective, and it is unclear whether the results are applicable to other populations. Also, the four dietary patterns extracted in our study explained only 33% of the total variance. However, the dietary patterns identified in our study and the proportion of variance explained were similar to those reported for other populations in Japan (15, 19, 27, 28). Third, except for staple foods, information on food consumption was limited to only frequency, and no information on the portion size was collected. In addition, analysis of the reliability and validity of the food frequency questionnaire has not been completed in the present study population, and is currently ongoing. Fourth, it is possible that the presence of various chronic diseases lead to changes in dietary habits. For instance, people who had been treated for dyslipidemia may have refrained from consuming high fat foods. However, even when the 50 subjects who had been under treatment for dyslipidemia were excluded, there was no significant positive correlation between the high fat/Western dietary pattern scores and the prevalence of high serum triglyceride levels. Fifth, dietary pattern scores were correlated with other aspects of lifestyle, such as physical activity and total energy intake. If there were random errors in measuring these factors, the possibility of residual confounding remains, even after statistical adjustments. Finally, the number of study subjects was rather small.

In conclusion, a prudent dietary pattern, characterized by high intake of vegetables and fruits, and a bread and dairy products pattern were associated with lower prevalence of some components of MetS. A high fat/Western dietary pattern was positively correlated with insulin resistance in a Japanese population. Further longitudinal studies are required to verify the cause-effect relationship.

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