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ORIGINAL ARTICLE

Relationship between number of metabolic syndrome components and dietary factors in middle-aged and elderly Japanese subjects

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Metabolic syndrome (MetS) represents a cluster of risk factors for atherosclerosis and is considered a risk factor for cardiovascular disease. The role of diet in the etiology of MetS is poorly understood, especially among Asian subjects. This cross-sectional study assessed the relationship between diet and the number of MetS components among Japanese men (*n*=609) and women (*n*=631). Mean (s.d.) age and body mass index were 57.1 (12.1) years and 22.8 (2.8) kg m^{-2} for men and 55.5 (12.0) years and 22.0 (3.0) kg m^{-2} for women, respectively. Diet was assessed by a 3-day dietary record that included photographs: 16 nutrients, 11 food groups, and energy % of protein and dietary fat were selected as a dietary index. The definition of MetS was based on modified National Cholesterol Education Program, Adult Treatment Panel III criteria, and the number of clustering MetS components was calculated by adding the presence of each five MetS components. A total of 61 men (10.0%) and 46 women (7.3%) were determined to have MetS. After adjusting for age, energy intake, alcohol intake, smoking status and physical activity, a lower intake of vitamin B6 and dietary fiber in men, and lower intake of calcium, milk and dairy products and higher intake of cereal in women were related to the number of MetS components. These results suggest that some dietary factors were related to the number of MetS components among community-dwelling Japanese men and women.
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Keywords: cross-sectional study; dietary record; Japanese; metabolic syndrome

INTRODUCTION

Metabolic syndrome (MetS) represents a cluster of risk factors for atherosclerosis, including visceral obesity, hypertension, dyslipidemia and hyperglycemia; MetS is considered a risk factor for cardiovascular disease.[1] The National Nutrition Survey in Japan, a population-based study among 40- to 74-year-olds, revealed that 24% of men and 12% of women were strongly suspected of having MetS, and 27% of men and 8% of women were suspected of having MetS.[2]

MetS has become a major public health challenge in Japan.[3] The pathophysiology of MetS appears to be largely attributable to insulin resistance with an excessive flux of fatty acids,[1] although this disorder presumably exists as a function of a complex interaction between environmental factors, including diet or physical activity and genetic factors.[4,5]

Although dietary aspects have been linked to individual features of MetS,[6–8] the role of diet in the etiology of this syndrome is poorly understood. Asians have different lifestyle and genetic factors compared with Caucasians,[9,10] but only a few epidemiologic studies examining diet and MetS among Asians have been conducted.[11–13] The aim of this study was to examine the relations between diet and the number of MetS factors among community-dwelling Japanese men and women.

METHODS

Study subjects

Data for this survey were collected as part of the National Institute for Longevity Sciences Longitudinal Study of Aging (NILS-LSA). In this project, the normal aging process has been assessed over time using detailed questionnaires and medical checkups, anthropometrical measurements, physical fitness tests and nutritional examinations. Participants in the NILS-LSA included randomly selected age- and sex-stratified individuals from the pool of residents in the NILS neighborhood areas, Obu City and Higashiura Town of Aichi Prefecture. Details of the NILS-LSA study are reported elsewhere.[14]

Subjects in this study included 1189 men and 1194 women aged 40–86 years who participated in the fourth wave of the NILS-LSA from June 2004 to July 2006. Subjects under non-pharmacological and/or pharmacological treatment for hypertension, hypertriglyceridemia or diabetes were excluded, as were subjects who indicated that they were aware of having these disorders but were not undergoing treatment. There were 334 men and 327 women with hypertension, 241 men and 174 women with hypertriglyceridemia and 104 men and 69 women with diabetes. As some subjects had multiple disorders, a total

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of 489 men and 492 women were excluded from the study. Additionally, subjects who did not fast overnight for venipuncture (11 men and 12 women), those who did not participate or complete the nutrition survey (54 men and 47 women) and those whose energy intake was <1200 kcal per day (2 men and 11 women) or more than 3000 kcal per day (24 men and 1 woman) were also excluded. After these exclusions, 609 men and 631 women remained in the study.

The study protocol was approved by the Committee of Ethics of Human Research of the National Center for Geriatrics and Gerontology. Written informed consent was obtained from all subjects.

Nutritional assessments

Nutritional intakes were assessed by a 3-day dietary record. The dietary record was completed over 3 continuous days (both weekend days and one weekday).[15] Food was weighed separately on a scale (1 kg kitchen scale, Sekisui Jushi, Tokyo, Japan) before being cooked or portion sizes were estimated. Subjects used a disposable camera (27 shots, Fuji Film, Tokyo, Japan) to take photos of meals before and after eating. Dietitians used the photos to complete missing data, and telephoned subjects to resolve any discrepancies or obtain further information when necessary. The averages of the 3-day food and nutrient intakes were calculated according to the fifth edition of the Standard Tables of Foods Composition in Japan and other sources.[15] Alcohol intake in the previous year was assessed by a food frequency questionnaire; trained dieticians interviewed subjects using this questionnaire. According to previous large epidemiological studies,[7,11] we selected 16 nutrients and 11 food groups as a dietary index, along with energy % of protein and dietary fat.

Other measurements

Anthropometric measurements included waist circumference, height and body weight. Waist circumference was measured at the umbilicus[16,17] and body mass index was calculated as weight/height^2 (kg m^{-2}). Blood pressure was measured by an automated sphygmomanometer (BP-203RVII, Omron Colin, Tokyo, Japan) after participants had been comfortably seated for at least 5 min. All venous blood samples were obtained after an overnight fast. The serum was separated promptly, and all lipid analyses were conducted at the clinical laboratory in the health examination center. Serum glucose and triglycerides were measured using enzymatic methods. HDL-cholesterol was measured after dextran sulfate-magnesium precipitation.

Medical history (past and current) and smoking status (yes/no) were collected using questionnaires. Physical activity was assessed by trained interviewers using the Met Score (a multiple of the resting metabolic rate). Participants were interviewed using a semi-quantitative assessment to determine their level of habitual physical activity during leisure time, on the job and sleeping hours,[18] and we calculated the total MetS*minutes score per day (MetS*1000 min per day). For example, walking for pleasure was assigned a 2.5 MetS intensity, and thus the leisure-time physical activity score was 50 MetS*min per day in the case of a 20 min walk every day.[18]

Definition of MetS and components

The definition of MetS was based on modified National Cholesterol Education Program, Adult Treatment Panel III (NCEP-ATP III) criteria.[19] Only the criteria of abdominal obesity was different from that of NCEP-ATP III criteria.[20] For abdominal obesity, we used the International Obesity task Force central obesity criteria for Asia, which defined abdominal obesity as a waist circumference of at least 90 cm for men and at least 80 cm for women.[21]

As stated earlier, study subjects under treatment for hypertension, hypertriglyceridemia and diabetes were excluded before the analyses. Thus, MetS was defined as the presence of three or more of the following five components: (1) abdominal obesity, defined as a waist circumference of at least 90 cm for men and at least 80 cm for women; (2) elevated blood pressure, defined as blood pressure $\geqslant$130/85 mm Hg; (3) hypertriglyceridemia, defined as triglycerides $\geqslant$150 mg per 100 ml ($\geqslant$1.70 mmol l^{-1}); (4) low HDL-cholesterol, defined as HDL-cholesterol $<$40 mg per 100 ml ($<$1.0 mmol l^{-1}) in men and $<$50 mg per 100 ml ($<$1.3 mmol l^{-1}) in women; and (5) elevated blood glucose levels, defined as fasting blood glucose $\geqslant$100 mg per 100 ml. The number of clustering MetS components was calculated by adding the number of MetS components.

Statistical analyses

All statistical analyses were conducted with Statistical Analysis System, release 9.1.3 (SAS Institute, Cary, NC, USA). Subjects were categorized into four groups according to the number of clustering MetS components (0, 1, 2, 3–5). Values of 3–5 were combined because only a few or no subjects had 4 or 5 MetS components (4 components: 12 men and 5 women; 5 components: 0 men and 2 women). Associations between categorical variables were tested by χ^2 test and 95% confidence interval (CI) was estimated using the PROC FREQ procedure. Comparisons between continuous variables were performed by analysis of variance and trend test. Linear regression models were constructed using the PROC GLM procedure to examine the association between the number of MetS components and dietary indexes, that is, the 11 food groups, 16 nutrients and energy % of protein and dietary fat. Mean nutritional intakes were calculated by the number of MetS components (0, 1, 2, 3–5) after multivariate adjustment for potential confounding factors, which included age, energy intake, alcohol intake, smoking status and physical activity. Additionally, demographic differences between subjects (609 men and 631 women) and those excluded from the study (580 men and 563 women) were analyzed by *t*-test.

All reported *P*-values were two-sided, and a *P*-value <0.05 was considered significant.

RESULTS

Subject characteristics are presented Table 1. Mean (s.d.) age and BMI were 57.1 (12.1) years and 22.8 (2.8) kg m^{-2} for men and 55.5 (12.0) years and 22.0 (3.0) kg m^{-2} for women, respectively. Age and BMI gradually increased with the number of MetS components in both men and in women, whereas mean age of subjects with 2 or 3–5 MetS components was similar in men (59.5 years and 59.5 years, respectively) and women (60.7 and 60.9 years, respectively).

Abdominal obesity, defined as waist circumference $\geqslant$90 cm, was noted in 20.0% of men (95% CI: 16.8–23.2), with a prevalence of 14.4, 41.9 and 70.5% among men with 1, 2 or 3–5 MetS components, respectively. Abdominal obesity, defined as waist circumference $\geqslant$80 cm, was noted in 44.1% of women (95% CI: 40.2–48.0), with a prevalence of 69.7, 84.5 and 97.8% among those with 1, 2 or 3–5 MetS components, respectively. Elevated blood glucose levels were seen in 38.1% of men and 17.9% of women according to the number of MetS components (1, 2 or 3–5) was 49.8, 61.5 and 91.8% in men and 17.1, 41.8 and 73.9% in women, respectively. Hypertriglyceridemia and hypertension were seen in 18.2 and 22.5% of men and 7.5 and 12.8% of women, respectively. Low HDL-C levels occurred in 5.9% of men and 7.0% of women. A total of 61 men (10.0%) and 46 women (7.3%) met the NCEP-ATP III modified criteria for MetS, that is, they had 3–5 MetS components.

In sub-analyses, demographic differences between subjects included in the study (609 men and 631 women) and those excluded from the study (580 men and 563 women) were analyzed. Age, BMI and the other anthropometric variables (for example, blood pressure, waist circumference or fasting glucose levels) were lower among subjects than those excluded (mean (s.d.) age: 56.9 (12.1) *vs.* 64.8 (11.7) years, mean BMI: 22.5 (2.9) *vs.* 23.6 (3.2) kg m^{-2}, respectively).

Table 2 shows multivariate adjusted mean food and nutrient intake according to the number of MetS components in men. Among the dietary indexes, daily intakes of vitamin B6 decreased from 1.36 to 1.21 mg, and dietary fiber decreased from 16.2 to 14.5 mg as the number of MetS components increased. Although analysis of covariance did not reach statistical significance, intake of vegetables was lower among men with higher number of MetS components, and decreased from 301.1 to 271.9 g as the number of MetS components increased (ANCOVA P=0.07, trend test P=0.03). In addition, although analysis of covariance or trend tests did not reach statistical

Table 1 Subject characteristics according to the number of metabolic syndrome (MetS) components

		Number of MetS components					
Variable	*All*	*0*	*1*	*2*	*3–5*	P[a]	*Trend* P
Men							
n, %	609 (100%)	222 (36.5%)	209 (34.3%)	117 (19.2%)	61 (10.0%)		
Age (year)	57.1 ± 12.1	55.1 ± 12.5	57.1 ± 11.7	59.5 ± 12.0	59.5 ± 11.0	<0.01	<0.01
Body mass index (kg m^{-2})	22.8 ± 2.8	21.7 ± 2.4	22.5 ± 2.5	24.0 ± 2.7	25.6 ± 2.6	<0.01	<0.01
Alcohol intake (g per day)	14.2 ± 17.3	12.7 ± 16.1	14.6 ± 17.1	15.9 ± 17.8	15.3 ± 21.2	0.38	0.24
Physical activity (MetS*1000 min per day)	2116 ± 302	2107 ± 290	2109 ± 266	2124 ± 334	2159 ± 389	0.65	0.21
Energy intake (kcal/)	2247 ± 335	2247 ± 308	2233 ± 342	2283 ± 337	2227 ± 399	0.59	0.95
Current smoker (*n*, %)	186 (30.5%)	62 (27.9%)	67 (32.1%)	38 (32.5%)	19 (31.2%)	0.76	
Metabolic abnormalities (n, %)							
Waist circumference ⩾90 (cm)	122 (20.0%)	0 (–%)	30 (14.4%)	49 (41.9%)	43 (70.5%)		
Triglyceride ⩾150 (mg per 100 ml)	111 (18.2%)	0 (–%)	24 (11.5%)	44 (37.6%)	43 (70.5%)		
HDL-cholesterol <40 (mg per 100 ml)	36 (5.9%)	0 (–%)	7 (3.4%)	17 (14.5%)	12 (19.7%)		
Blood pressure ⩾130/85 mm Hg	137 (22.5%)	0 (–%)	44 (21.1%)	52 (44.4%)	41 (67.2%)		
Fasting glucose ⩾100 mg per 100 ml	232 (38.1%)	0 (–%)	104 (49.8%)	72 (61.5%)	56 (91.8%)		
Women							
n, %	631 (100%)	272 (43.1%)	210 (33.3%)	103 (16.3%)	46 (7.3%)		
Age (year)	55.5 ± 12.0	51.5 ± 10.9	56.8 ± 12.1	60.7 ± 11.8	60.9 ± 10.9	<0.01	<0.01
Body mass index (kg m^{-2})	22.0 ± 3.0	20.2 ± 1.9	22.7 ± 2.7	23.6 ± 3.0	25.4 ± 3.2	<0.01	<0.01
Alcohol intake (g per day)	3.4 ± 7.6	3.7 ± 7.3	3.2 ± 7.7	2.3 ± 5.3	4.6 ± 12.1	0.27	0.60
Physical activity (MetS*1000 min per day)	2161 ± 160	2187 ± 152	2144 ± 169	2132 ± 131	2143 ± 201	<0.01	0.07
Energy intake (kcal/	1884 ± 288	1884 ± 299	1878 ± 293	1893 ± 275	1895 ± 229	0.97	0.72
Current smoker (*n*, %)	39 (6.2%)	21 (7.7%)	9 (4.3%)	4 (3.9%)	5 (10.9%)	0.17	
Metabolic abnormalities (n, %)							
Waist circumference ⩾80 (cm)	278 (44.1%)	0 (–%)	146 (69.7%)	87 (84.5%)	45 (97.8%)		
Triglyceride ⩾150 (mg per 100 ml)	47 (7.5%)	0 (–%)	6 (2.9%)	21 (20.4%)	20 (43.5%)		
HDL-cholesterol <50 (mg per 100 ml)	44 (7.0%)	0 (–%)	8 (3.8%)	19 (18.5%)	17 (37.0%)		
Blood pressure ⩾130/85 mm Hg	81 (12.8%)	0 (–%)	14 (6.7%)	36 (35.0%)	31 (67.4%)		
Fasting glucose ⩾100 mg per 100 ml	113 (17.9%)	0 (–%)	36 (17.1%)	43 (41.8%)	34 (73.9%)		

Values shown are mean ± s.d.
[a]Statistical significance was determined by analysis of variance or χ^2 test.

significance, higher daily intakes of cholesterol (379.2–404.6 mg) and eggs (52.5–58.2 g) were related to an increased number of MetS components (trend test $P<0.1$).

In women (Table 3), intake of calcium decreased from 609.2 to 549.9 mg daily, and intake of milk and dairy food decreased from 181.2 to 134.9 mg daily as the number of MetS components increased. Cereal intake increased from 382.3 to 418.4 g daily as the number of MetS components increased. Although analysis of covariance and trend test did not reach statistical significance, lower intake of saturated fat was related to an increased number of MetS components, and decreased from 15.7 to 14.8 g daily as MetS components increased (trend test $P<0.1$).

DISCUSSION

Our findings suggest that lower intakes of vitamin B6 and dietary fiber in men, and lower intakes of calcium, milk and dairy products and higher intake of cereal in women are related to the number of MetS components. To our knowledge, this is the first observational study to examine relations between dietary factors and the number of clustering MetS components among Japanese men and women.

In previous epidemiologic studies, dietary fiber, fruits, vegetables and moderate alcohol intake were negatively associated[22–24] and fat and red meat were positively associated[25–27] with MetS in Caucasian or Japanese-Brazilian subjects. Consistent with previous studies,[22,24,28] intake of dietary fiber in men was negatively related to clustering MetS components. Diets rich in dietary fiber are associated with a reduced risk of diabetes and cardiovascular disease. Dietary fiber has a higher satiety value compared with digestible complex carbohydrates and simple sugars because of its bulk and relatively low energy. Fiber may also affect secretion of gut hormones or peptides, such as cholecystokinin or glucagon-like peptid-1, which may act as satiety factors or alter glucose homeostasis.[28,29] Thus, an increased fiber intake may prevent MetS.

Although carbohydrate intake in women did not correlate with the number of MetS components, cereals that mainly consisted of carbohydrates showed a negative effect on the number of MetS components in this study. Carbohydrates are also implicated in changes in blood glucose and insulin concentrations and are known to affect satiety.[30] The beneficial effect of a high carbohydrate diet on glucose tolerance has been reported;[31] however, contradicting reports have also been published.[32–36] Dietary carbohydrate through cereal intake is thought to modulate lipolysis, and a low-carbohydrate diet reduces cardiovascular risk through improvement in hepatic, intravascular and peripheral processing of lipoproteins.[32] Although no positive relation was

Table 2 Energy and multivariate adjusted[a,b] mean food and nutrient intake according to the number of metabolic syndrome (MetS) components in men (n=609)

	Number of MetS components					
Variable	*0*	*1*	*2*	*3–5*	P[c]	*Trend* P
n (%)	222 (36.5%)	209 (34.3%)	117 (19.2%)	61 (10.0%)		
Energy (kcal)	2247 ± 23	2233 ± 23	2283 ± 31	2227 ± 43	0.59	0.95
Nutrients[a]						
Protein (energy %)	3.71 ± 0.03	3.71 ± 0.03	3.71 ± 0.05	3.70 ± 0.06	0.99	0.93
Fat (energy %)	2.71 ± 0.03	2.67 ± 0.04	2.66 ± 0.05	2.79 ± 0.07	0.35	0.36
Carbohydrate (energy %)	13.8 ± 0.1	14.0 ± 0.1	14.0 ± 0.2	13.8 ± 0.2	0.62	0.98
Nutrients[b]						
Protein (g)	82.9 ± 0.7	82.8 ± 0.8	83.5 ± 1.0	82.5 ± 1.4	0.93	0.92
Fat (g)	61.2 ± 0.8	60.3 ± 0.8	60.4 ± 1.1	62.8 ± 1.5	0.46	0.33
Carbohydrate (g)	310.3 ± 2.4	312.7 ± 2.5	312.1 ± 3.3	309.8 ± 4.6	0.89	0.88
Calcium (mg)	619.5 ± 12.4	604.2 ± 12.6	590.1 ± 17.0	588.8 ± 23.5	0.47	0.20
β-Carotene (μg)	3269 ± 118	3274 ± 121	2804 ± 163	3003 ± 225	0.08	0.11
Vitamin E (mg)	9.8 ± 0.2	9.5 ± 0.2	9.1 ± 0.2	9.3 ± 0.3	0.130	0.10
Vitamin B6 (mg)	1.36 ± 0.02	1.35 ± 0.02	1.29 ± 0.03	1.21 ± 0.04	0.006	0.001
Vitamin B12 (μg)	8.8 ± 0.4	8.2 ± 0.4	9.4 ± 0.5	8.0 ± 0.7	0.23	0.70
Folate (μg)	343.6 ± 7.3	352.6 ± 7.5	339.9 ± 10.1	340.4 ± 13.9	0.70	0.65
Vitamin C (mg)	126.4 ± 7.1	127.2 ± 7.2	135.1 ± 9.7	125.1 ± 13.4	0.89	0.93
Saturated fat (g)	16.5 ± 0.3	15.9 ± 0.3	16.0 ± 0.4	16.1 ± 0.5	0.58	0.57
Monounsaturated fat (g)	21.2 ± 0.4	20.8 ± 0.4	20.8 ± 0.5	21.5 ± 0.7	0.66	0.70
Polyunsaturated fat (g)	13.3 ± 0.2	13.4 ± 0.2	13.5 ± 0.3	14.0 ± 0.4	0.55	0.15
Cholesterol (mg)	379.2 ± 8.8	369.0 ± 9.0	396.7 ± 12.2	404.6 ± 16.8	0.15	0.08
Dietary fiber (g)	16.2 ± 0.3	15.9 ± 0.3	14.8 ± 0.4	14.5 ± 0.5	0.002	0.001
Salt (g)	11.8 ± 0.1	12.1 ± 0.1	11.9 ± 0.2	11.6 ± 0.3	0.29	0.28
Foods						
Cereals (g)	512.2 ± 7.5	522.6 ± 7.7	538.3 ± 10.3	512.9 ± 14.2	0.21	0.72
Beans (g)	76.5 ± 4.7	86.9 ± 4.8	86.6 ± 6.4	82.8 ± 8.9	0.41	0.55
Nuts and seeds (g)	6.0 ± 0.6	4.0 ± 0.6	3.9 ± 0.8	5.4 ± 1.2	0.07	0.61
Vegetables (g)	301.1 ± 7.9	304.5 ± 8.1	277.0 ± 10.9	271.9 ± 15.0	0.07	0.03
Fruits (g)	137.1 ± 7.1	130.8 ± 7.3	122.0 ± 9.8	134.3 ± 13.5	0.66	0.72
Fish and shellfish (g)	111.2 ± 3.5	107.1 ± 3.6	109.3 ± 4.9	108.3 ± 6.7	0.88	0.79
Meats (g)	86.2 ± 3.1	89.4 ± 3.2	93.9 ± 4.2	95.0 ± 5.9	0.38	0.13
Eggs (g)	52.5 ± 1.9	53.5 ± 1.9	59.5 ± 2.6	58.2 ± 3.6	0.11	0.07
Milk and dairy food (g)	163.6 ± 8.0	144.3 ± 8.1	140.7 ± 10.9	129.8 ± 15.1	0.12	0.049
Fats and oils (g)	11.3 ± 0.4	11.6 ± 0.4	11.6 ± 0.6	11.6 ± 0.8	0.97	0.77
Confectioneries (g)	45.1 ± 3.3	46.6 ± 3.4	43.2 ± 4.5	46.7 ± 6.3	0.94	0.95

Values shown are mean ± s.e.
[a]Adjusted for age, alcohol intake, smoking and physical activity.
[b]Adjusted for age, energy intake, alcohol intake, smoking and physical activity.
[c]Statistical significance was determined by analysis of covariance.

shown between carbohydrate intake and the number of MetS components in this study, recent nutritional reviews indicate that the quantity and type of carbohydrate affect metabolic outcomes.[35] Among cereals, whole grain products that have a lower glycemic index and are richer in fiber and antioxidant vitamins than refined grain products were suggested to improve insulin sensitivity, probably by blunting postprandial glycemic and insulinemic responses.[36] Thus, control of these factors in future studies will be important to determine the most effective dietary approach to prevent metabolic disorders.

In Japan, there has been a significant reduction in the intake of cereals, and rice in particular, in recent decades,[2,37] On the other hand, dietary fat intake is increasing, and consumption of a more Westernized diet is thought to be associated with the evident increase in diabetes mellitus and obesity. In women in this study, saturated fat intake weakly decreased as the number of MetS components increased. Dietary intervention studies show that total fat is not associated with the risk of MetS, although saturated fats increase the risk of MetS, whereas monounsaturated and polyunsaturated fats reduce this risk.[38–40] Our results do not agree with studies that show that saturated fat-rich lipid infusion reduces the insulin sensitivity index more than polyunsaturated fat infusion.[41] Although the reason of this inverse relation was shown in this study is not clear, two possibilities can be considered. First, some intermediate event, such as dietary counseling, could have lead to changes in diet and might have confounded the association between saturated fat intake and metabolic

Table 3 Energy and multivariate adjusted[a,b] mean food and nutrient intake according to the number of metabolic syndrome (MetS) components in women (n=631)

	Number of MetS components					
Variable	*0*	*1*	*2*	*3–5*	P[c]	*Trend* P
n (%)	272 (43.1%)	210 (33.3%)	103 (16.3%)	46 (7.3%)		
Energy (kcal)	1884 ± 18	1878 ± 20	1893 ± 29	1896 ± 43	0.97	0.72
Nutrients[a]						
Protein (energy%)	3.75 ± 0.03	3.84 ± 0.03	3.79 ± 0.05	3.70 ± 0.07	0.15	0.45
Fat (energy%)	2.97 ± 0.03	2.94 ± 0.03	2.93 ± 0.05	2.91 ± 0.07	0.85	0.46
Carbohydrate (energy%)	14.2 ± 0.1	14.2 ± 0.1	14.1 ± 0.2	14.2 ± 0.2	0.97	0.99
Nutrients[b]						
Protein (g)	70.2 ± 0.5	71.9 ± 0.6	71.4 ± 0.9	69.7 ± 1.3	0.16	0.64
Fat (g)	56.4 ± 0.6	55.7 ± 0.7	55.5 ± 0.9	54.7 ± 1.4	0.67	0.28
Carbohydrate (g)	267.4 ± 1.8	266.2 ± 2.0	265.4 ± 2.9	268.2 ± 4.3	0.91	0.93
Calcium (mg)	609.2 ± 11.0	604.8 ± 12.3	556.3 ± 17.9	549.9 ± 26.4	0.024	0.01
β-Carotene (μg)	3358 ± 112	3263 ± 125	2931 ± 181	3508 ± 268	0.18	0.90
Vitamin E (mg)	9.1 ± 0.1	9.0 ± 0.2	9.0 ± 0.2	9.4 ± 0.3	0.70	0.35
Vitamin B6 (mg)	1.13 ± 0.02	1.19 ± 0.02	1.13 ± 0.03	1.15 ± 0.04	0.11	0.98
Vitamin B12 (μg)	6.9 ± 0.3	7.0 ± 0.4	7.4 ± 0.5	6.9 ± 0.8	0.87	0.95
Folate (μg)	333.9 ± 6.8	342.7 ± 7.6	334.2 ± 11.0	360.0 ± 16.3	0.45	0.21
Vitamin C (mg)	121.7 ± 4.2	125.6 ± 4.7	111.0 ± 6.9	131.7 ± 10.1	0.24	0.66
Saturated fat (g)	15.7 ± 0.2	15.5 ± 0.3	15.0 ± 0.4	14.8 ± 0.6	0.23	0.07
Monounsaturated fat (g)	19.1 ± 0.3	19.0 ± 0.3	19.1 ± 0.4	18.8 ± 0.6	0.96	0.74
Polyunsaturated fat (g)	12.1 ± 0.2	12.0 ± 0.2	12.2 ± 0.3	12.2 ± 0.4	0.91	0.67
Cholesterol (mg)	321.1 ± 6.7	339.2 ± 7.4	343.1 ± 10.8	318.7 ± 15.9	0.16	0.95
Dietary fiber (g)	15.2 ± 0.2	15.7 ± 0.3	15.2 ± 0.4	15.5 ± 0.5	0.49	0.82
Salt (g)	10.4 ± 0.1	10.4 ± 0.1	10.6 ± 0.2	10.8 ± 0.3	0.45	0.11
Foods[b]						
Cereals (g)	382.3 ± 5.2	385.8 ± 5.8	400.3 ± 8.4	418.4 ± 12.4	0.03	0.004
Beans (g)	75.4 ± 4.1	80.7 ± 4.6	76.0 ± 6.6	83.1 ± 9.8	0.77	0.58
Nuts and seeds (g)	6.3 ± 0.7	6.9 ± 0.7	6.2 ± 1.1	5.3 ± 1.6	0.81	0.48
Vegetables (g)	285.4 ± 6.5	285.1 ± 7.3	275.2 ± 10.6	322.6 ± 15.6	0.09	0.06
Fruits (g)	152.1 ± 6.7	160.9 ± 7.5	145.3 ± 10.9	131.0 ± 16.1	0.32	0.15
Fish and shellfish (g)	81.9 ± 2.5	89.3 ± 2.8	90.7 ± 4.1	84.2 ± 6.1	0.16	0.69
Meats (g)	65.5 ± 2.0	70.8 ± 2.3	71.1 ± 3.3	66.1 ± 4.9	0.27	0.90
Eggs (g)	48.2 ± 1.6	52.1 ± 1.8	53.1 ± 2.6	50.6 ± 3.9	0.33	0.54
Milk and dairy food (g)	181.2 ± 6.7	177.0 ± 7.4	153.7 ± 10.8	134.9 ± 16.0	0.018	0.003
Fats and oils (g)	11.2 ± 0.3	10.7 ± 0.4	10.6 ± 0.6	10.2 ± 0.8	0.64	0.28
Confectioneries (g)	65.5 ± 2.7	61.6 ± 3.0	60.1 ± 4.4	56.9 ± 6.5	0.52	0.21

Values shown are mean ± s.e.
[a]Adjusted for age, alcohol intake, smoking and physical activity.
[b]Adjusted for age, energy intake, alcohol intake, smoking and physical activity.
[c]Statistical significance was determined by analysis of covariance.

risks. We tried to exclude subjects from the analysis who were aware of their potential risks and who may have made dietary changes based on perceived dangers. Second, Japanese subjects consume a relatively large amount of fish containing abundant polyunsaturated fatty acids. The ratio of saturated fat to polyunsaturated fat might be more important than the absolute intake considering the physiologic dietary effect on developing MetS. These factors might have affected our results. Further studies are needed to clarify the role of fat quality in the prevention of MetS.

Calcium, milk and dairy food intake in women decreased with the increase in the number of MetS components. Additionally, although findings were not statistically significant, a similar relation between milk and dairy products and MetS was shown in men (ANCOVA $P=0.12$, trend $P=0.049$). Diets rich in calcium, particularly calcium derived from dairy products, have been shown to be associated with a low prevalence of MetS.[42] The mechanism by which calcium intake can reduce MetS is unclear, but Scholz-Ahrens and Schrezenmeir[42] implied that dietary calcium intake has benefits on traits of MetS, specifically on weight reduction and fat loss. Meijl *et al.*[43] reviewed the physiological effects of three main dairy constituents (calcium, protein and fat) on MetS, and indicated that the effects of calcium might be related to intestinal binding to fatty acids or bile acids or to changes in intracellular calcium metabolism by suppressing calciotropic hormones. In an epidemiologic study, Otsuka *et al.*[44] reported that higher milk consumption was associated with a lower incidence of MetS after 5 years among middle-aged

Japanese male workers, suggesting that calcium derived from dairy products might help prevent MetS.

Vitamin B6 in men was also negatively related to the number of MetS components. Esmaillzadeh *et al.*[45] discussed the favorable effect of whole grain on MetS through the rich content of viscous fiber and showed that intake of whole grains was positively associated not only with dietary fiber (r=0.43) but also with vitamin B6 (r=0.48). Consistent with their study, the results of our study showed favorable effects of dietary fiber and vitamin B6 on the number of MetS components. Hayden and Tyagi[46] reported on the role of water soluble B vitamins, including vitamin B6, in lowering plasma total homocysteine, a risk marker of MetS, through remethylation. Although the precise mechanism of vitamin B6 on MetS is unclear, a favorable association of vitamin B6 to MetS in men may be attributed to a healthier diet that contained rich fiber, milk and dairy products or vegetables.

Although not statistically significant, lower intake of vegetables in men was related to an increased number of MetS components. Higher vegetable intake has been previously reported as a protective factor of MetS or inflammation in women.[7,22] Vegetables rich in dietary fiber are thought to reduce the risk of developing MetS by improving glucose control, and minerals, antioxidants or vitamins contained in vegetables are thought to have a favorable effect on glucose tolerance.[47,48] Our results regarding dietary fiber on MetS may represent the positive effect of vegetable intake.

In men, higher intakes of eggs and cholesterol were related to an increased number of MetS components, although this was not statistically significant (trend $P<0.1$). Excess consumption of eggs should be avoided from the standpoint of preventing hypercholesterolemia among Japanese subjects.[49] Increased dietary cholesterol intake is associated with atherosclerosis.[50] The result of this study may suggest that men with a lower number of MetS components tend to abstain from eating eggs or cholesterol-rich foods. As a result, a dose–response relationship between egg consumption and the number of MetS components was shown in our study.

The lack of other correlations between the number of MetS components and dietary factors, such as fruits, or meats in this study is thought to be due to differences in dietary intake[51] or metabolic responses[9,10] between Caucasian and Japanese subjects.

The relation of diet to the risk of MetS has been examined in many studies, but few have addressed the association with the number of MetS components.[52–54] We considered that the number of MetS components is more closely assessed through the effects of diet, that is, through a dose–response relationship, rather than the prevalence of MetS. In addition, to focus on the dose–response relationship, trend test by general linear model was used, and further *post hoc* analyses were not performed. MetS is a cluster of atherosclerotic cardiovascular disease risk factors[20] but there are some different criteria of MetS in Japan. The ideal threshold for waist circumference used to define abdominal obesity among Japanese men and women is still under discussion.[55] Recently, Kokubo *et al.*[19] reported that the number of MetS components (modified NCEP-ATP III criteria) might be more strongly associated with the incidence of cardiovascular disease than the presence of abdominal obesity (the Japanese criteria) in a general urban Japanese population. We used a modified NCEP-ATP III criteria, that is, a cutoff point of waist circumference that was different from NCEP ATP III (102 cm in men and 88 cm in women, modified: 90 cm in men and 80 cm in women), in this study.[20,21]

Several limitations of this study warrant consideration. First, the cross-sectional nature of the study did not permit the assessment of causality. Subjects under treatment for hypertension, hypertriglyceridemia or diabetes or those aware of morbidities might have modified their food intake, and these subjects were excluded from analysis. However, some plausible relationships between foods or nutrients and MetS have been identified in this study. NILS-LSA, which is a population-based prospective cohort study, followed participants for more than 10 years. Future analyses should examine the associations between the dietary index and MetS.

Second, we used foods and nutrients as an indicator of diet, although these items are consumed in combination, and their complex effects are likely to be interactive or synergistic.[56] Consumption of several foods or food groups might be a more comprehensive variable to assess the impact of diet on disease risk than any single nutrient or food. Third, nutritional intakes were assessed by a 3-day dietary records. The 3-day dietary record is one of the most reliable methods for nutritional assessment; however, it is limited because individual food intake varies greatly from day to day,[15] and it is not clear whether short-term records adequately reflect long-term dietary intake.[57] On the basis of this limitation, we preliminarily decided on 3 continuous days (both weekend days and one weekday) to avoid events or special days such as trips, long vacations or out-of-the-ordinary events and thus minimize food variations. Although the 3-day dietary record is not the best way to assess long-term dietary intake, it can be considered to have a certain level of accuracy that reflects the usual nutrient intakes in this cohort.

Fourth, food consumption and nutrient intake among Japanese have dramatically changed during the past five decades. For example, Westernization of the Japanese diet has lead to decreased consumption of carbohydrates, especially rice, and increased consumption of fat and meat.[2,37] In particular, younger Japanese subjects tend to eat a more Westernized diet.[37] As a result, not only food intake but also the number MetS components might differ among different generations of Japanese subjects. Thus, it may be difficult to detect statistically significant relationships between diet and the number of MetS components in the age group we studied.

In summary, this study showed that some foods and nutritional components are related to the number of MetS components. These results suggest the potential effect of diet on the prevention of MetS among community-dwelling Japanese men and women.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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