J Rural Med 2013; **8**(1): 161–170

Original article

Daily Rice Intake Strongly Influences the Incidence of Metabolic Syndrome in Japanese Men Aged 40–59 Years

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Abstract

Objectives: The first objective of this study was to classify men aged 40–74 yrs with metabolic syndrome (MetS) according to daily rice intake, and the second was to investigate physical measurements, physiological examinations, blood biochemical assays, intake of food other than rice and lifestyle and environmental factors in the study group. **Methods:** We analyzed data from 6095 men aged 40–74 yrs who had undergone full medical examinations. The men were classified into 3 age groups: (1) 40–49 yrs, (2) 50–59 yrs, and (3) 60–74 yrs. The men were classified further into 3 groups according to daily rice intake: group 1 (≤300 g), group 2 (300–450 g), and group 3 (≥450 g). The relationship between daily rice intake and the following factors was analyzed in the three age brackets: (1) physical measurements including waist circumference, (2) physiological measurements, (3) serum biochemical indices, (4) whether or not the person was taking medication for hypertension, diabetes mellitus or serum lipid abnormalities, (5) lifestyle, and (6) consumption of foods other than rice. **Results:** Daily rice intake was related strongly to the occurrence of MetS in all three age brackets. Multiple logistic regression analysis showed (1) a significant increase in the odds ratio for MetS (1.461 times) for group 3 compared with group 1 in men aged 40–49 yrs and (2) a significant increase in the odds ratio for MetS (1.501 times) for group 3 compared with group 1 in men aged 50–59 yrs. However, there was no significant difference in the odds ratio for MetS among rice intake groups in the 60–74 age bracket. **Conclusion:** In men aged 40–59 yrs, daily rice intake strongly influenced the incidence of MetS, whereas in men aged 60–74 yrs, there was no relationship between daily rice intake and MetS.

Key words: rice intake, metabolic syndrome, men

(J Rural Med 2013; 8(1): 161–170)

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Introduction

The metabolic syndrome (MetS) is the term given to a cluster of conditions including central obesity, hypertension, diabetes mellitus, and abnormal serum lipid levels that lead to an increased likelihood of atherogenic disorders such as stroke and cardiovascular disease[1)]. Several reports have indicated that even if fasting blood triglycerides (TG), blood sugar and blood pressure are high but do not actually meet the cutoff for MetS, the combined effect of these conditions can cause up to a tenfold increase in the incidence of coronary heart disease[2)].

The criteria for MetS are met if a person has central obesity (excessive fat tissue in and around the abdomen) and one or more of the following conditions: high fasting blood triglycerides (≥150 mg/dl), low HDL cholesterol (≤40 mg/dl), high blood pressure (≥130/85 mmHg) or high fasting blood sugar (≥110 mg/dl). MetS develops as a result of accumulated storage of fat, with early diagnosis and treatment of obesity playing an important role in preventing atherogenic disorders. Central obesity is often associated with an unhealthy lifestyle, involving a diet high in calories and lack of physical exercise. Previous reports have suggested that the development of MetS is related to the type and amount of food consumed and insufficient burning of calories due to lack of exercise[3)]. In April 2000, measurement of waist circumference, one indicator of central obesity, was introduced as part of the annual medical examinations carried out in Japan under the National Health Promotion Law.

It is well established that excessive intake of sugar is a cause of central obesity. Intake of carbohydrates, particularly simple sugars, in excess of that used for physical activity, leads to fat accumulation, which in turn causes MetS. This study analyzed data from comprehensive medical examinations (*Ningen Dock*) carried out at the JA Ehime *Koseiren*

Center for Medical Examination (JA-EKCME) to examine the relationship between rice intake and the incidence of MetS in Japanese men. This study focused on rice consumption, as rice is a staple food in Japan. Physical measurements, physiological tests, blood tests, the frequency and volume of food intake, and lifestyle factors such as living arrangements were recorded and analyzed in a group of men classified according to age and their daily intake of rice.

Materials and Methods

Participants

The participants in the study were men aged 40–74 yrs who underwent a complete medical examination at the JA-EKCME between April 2008 and November 2010. The participants filled out a questionnaire on diet, physical exercise, sleeping habits, family structure, smoking habits, alcohol intake, other lifestyle-related factors and issues related to MetS, as well as a detailed nutrition intake questionnaire that was developed specifically for this study. The participants underwent body measurements including waist circumference, a physiological examination including measurement of blood pressure, and blood tests including serum total cholesterol.

Accuracy of interview information

Prior to the medical examination at JA-EKCME, public health nurses and nationally-registered dieticians received training in interview techniques for obtaining accurate food intake information and then conducted detailed interviews pertaining to the lifestyles of the participants, including diet.

The JA-EKCME questionnaire was a partiallyrevised version of the 29-question FFQg (food frequency questionnaire based on group) survey (version 2.0) and was designed to assess nutritional intake during an average day. To confirm the accuracy of the questionnaire, a pre-survey questionnaire was administered to 70 volunteers from JA-EKCME using the 24-hour recall method, in which volunteers took photographs of their meals over the 24-hour period prior to filling out the detailed questionnaire on nutritional intake[4]. The answers to the questionnaire were then compared with the photographs of the food consumed in the preceding 24 hours. When photographs were not available, simple food models were used in an effort to gauge the accuracy of the survey. We confirmed that our original questionnaire on food intake had adequate accuracy and validity for calculating nutritional intake.

Accuracy of cholesterol measurements

JA-EKCME is a member of the Lipid Standardization Program of the Centers for Disease Control (CDC) in Atlanta, GA, USA, and has received certification for accurate testing of total cholesterol (T-CHO), low density cholesterol (LDL-C), and high density cholesterol (HDL-C). The laboratory also internally monitors the accuracy of its own cholesterol measurements and evaluates all clinical and reference testing.

MetS criteria

The criteria for MetS require an individual to have central obesity (excessive fat tissue in and around the abdomen), defined as a waist circumference greater than 85 cm in men and 90 cm in women, and one or more of the following conditions: high fasting blood TG (≥150 mg/dl), low HDL-C (≤40 mg/dl), high blood pressure (≥130/85 mmHg) or high fasting blood sugar (≥110 mg/dl).

Age group classification

The participants were divided into 3 age groups, 40–49, 50–59 and 60–74 yrs, and the following data were analyzed for each group: physical measurements including waist circumference, physiological measurements including blood pressure, serum biochemistry including T-CHO, lifestyle factors related to exercise, sleeping habits, living arrangements, smoking habits, alcohol intake, nutritional intake and a number of MetS-related factors defined by the Ministry of Health, Labour and Welfare recorded in annual medical examinations.

Univariate analysis

One-way analysis of variance (ANOVA) and Tukey's multiple comparisons test were used to determine whether there were statistically significant differences between the 3 rice intake groups (groups 1, 2 and 3) for the following 10 continuous variables: age; consumption of eggs, milk and sugared and alcoholic beverages; and 5 serum biochemical markers: T-CHO, HDL-C, LDL-C, TG and Hemoglobin A1c (HbA1c).

We also determined the number of participants who took medication for hypertension, diabetes mellitus or dyslipidemia. Even if a participant's symptoms were well controlled by these medications, the participant was categorized as having that component of MetS. We did not consider medications for these three conditions to be confounding factors.

A Chi-square test was performed to determine whether or not there was a statistically significant difference between the three rice intake groups for the following 18 categorical data items: daily fruit intake, daily snacking, living arrangements (alone, as a couple, other), level of daily physical activity, frequency of checking body weight and 11 questions (Q8–Q17 and Q20) from the specific questionnaire on MetS[5].

Quantification and classification of foods

Intake of the following five types of foods and beverages was quantified: rice, eggs, milk, sugared beverages and alcoholic beverages. In addition, participants were classified according to their daily intake of fruit and the frequency and volume of snacking over a one-week period.

Rice intake was categorized based on the 33.3% and 66.7% percentiles as follows: group 1 (intake <300 g/day), group 2 (300–450 g/day) and group 3 (intake ≥450 g/day). The 2010 National Health and Nutrition Survey reported that the average daily rice intake for Japanese is 341.6 g. Because this average value falls within group 2 –the middle group– our categorization is reasonable[6].

Multiple logistic regression analysis

Using data stratified according to age, the odds ratio for the presence of MetS according to rice intake was calculated using multiple logistic regression analysis. The dependent factor was the presence or absence of MetS. The covariant factor, rice intake, consisted of 2 new dummy variables: comparison of groups 1 and 2 and groups 1 and 3.

Development of logistic mode analysis 1

To exclude the effects of age within the three age brackets, age was considered a covariant factor. Two-factor logistic model analysis was performed with the presence or absence of MetS as the dependent factor, rice intake (categorical data) as the independent factor, and age as a covariant factor.

Development of logistic mode analysis 2

To exclude the effects of all confounding factors, multiple logistic model analysis was performed with the presence or absence of MetS as the dependent factor, rice intake (categorical data) as the independent factor and the following factors as covariables: age, level of daily physical activity, frequency of checking body weight, living arrangements, a body weight gain ≥10 kg since the age of 20, eating quickly compared with other people, going to bed within 2 hours of having dinner 3 or more times per week, snacking 3 or more times per week, skipping breakfast 3 or more times per week, weekly egg consumption, daily milk consumption, daily sugared beverage consumption, weekly alcohol consumption, and daily fruit consumption. The covariables included in model 2 were shown by the Chi-square test to be significantly different in the rice intake groups.

The statistical analyses were performed using SPSS version 19 (IBM Japan). A P-value ≤0.05 was considered statistically significant.

Prior to the study, the purpose, content, and strict confidentiality of the investigations was explained to the participants, and individual written, informed consent was then obtained. The Ethics Committee of the Ehime Prefectural Federation of Agricultural Cooperatives for Health and Welfare (JA Ehime *Kouseiren*) approved the study prior to its implementation.

Results

Demographic characteristics

Of the 6,095 men analyzed, 2,929 (48%) were in group 1, 2,376 (39%) were in group 2, and 790 (13%) were in group 3. Table 1 shows the age distribution in each group.

Of the 2,253 men (37.0%) in the 40–49 yrs group, 1,122 (49.8%), 810 (36.0%), and 321 (14.2%) were in groups 1, 2 and 3, respectively.

Of the 2,786 men (45.7%) in the 50–59 yrs group, 1,335 (47.9%), 1,102 (39.6%), and 349 (12.5%) were in groups 1, 2 and 3, respectively.

Of the 1,056 men (17.3%) in the 60–74 yrs group, 472 (44.7%), 464 (43.9%), and 120 (11.4%) were in groups 1, 2 and 3, respectively.

Differences in physical measurements and serum biochemical indices in the three rice intake groups

Body mass index (BMI), percentage body fat content, waist circumference, systolic blood pressure, T-CHO, HDL-C, and HbA1c measurements were significantly different between the 3 rice intake groups.

In the 40–49 yrs and 50–59 yrs groups, BMI, body fat, waist circumference, and HbA1c increased as rice intake increased, whereas in the 60–74 yrs group, these variables all decreased with higher rice intake. T-CHO and HDL-C levels decreased with greater rice intake in the three groups.

A second statistical test, Tukey's multiple comparison test, was performed on seven factors (BMI, percentage body fat, waist circumference, systolic blood pressure, T-CHO, HDL-C, and HbA1c) shown by one-way analysis of variance to be significantly different between the rice intake groups. These tests compared group 1 to groups 2 and 3. BMI and waist circumference in men aged 40–49 yrs were significantly different between the groups 1 and 2 and groups 1 and 3, while HDL-C and HbA1c were only significantly different between groups 1 and 3.

In men aged 50–59 yrs, BMI, percentage body fat, waist circumference, systolic blood pressure, T-CHO, HDL-C, and HbA1c were significantly different between groups 1 and 3. In the 60–74 age bracket, only age and T-CHO were significantly different between groups 1 and 3.

Relationship between rice intake and prevalence of MetS

Six hundred and sixty-three men (22.6%) in group 1,585

Table 1 Physical measurements of men classified by the volume of rice intake per day

40–49 yrs old	Group 1 <300 g/day	Group 2 300–450 g/day	Group 3 >450 g/day	P value
Number of people	1122	810	321	
Age	45	45	45	0.347
BMI (kg/m^2)	24.2	24.7†	26.1††	0.000
Body fat (%)	23.4	23.9	25††	0.000
Waist circumference (cm)	85.4	86.8†	89.9††	0.000
Systolic blood pressure (mmHg)	118	120	120	0.052
Diastolic blood pressure (mmHg)	76	77	77	0.270
T-CHO (mg/dl)	206	206	205	0.735
HDL-C (mg/dl)	57	56	53††	0.000
LDL-C (mg/dl)	130	130	132	0.401
TG (The median) (mg/dl)	118	125	134	0.465
HbA1c (%)	5.2	5.3	5.3††	0.017
Number with MetS (%)	18.4	22.8	26.9	0.000□
Percentage taking medication for hypertension (%)	10.2	10.4	9.3	0.868□
Percentage taking medication for abnormal serum lipids (%)	5.3	6.8	6.9	0.303□
Percentage taking medication for diabetes mellitus (%)	2.9	3.3	5.3	0.101□
50–59 yrs old	**Group 1 <300 g/day**	**Group 2 300–450 g/day**	**Group 3 >450 g/day**	**P value**
Number of people	1335	1102	349	
Age	54	54	54	0.912
BMI (kg/m^2)	24	24.2	24.9††	0.000
Body fat (%)	22.7	22.8	23.5††	0.027
Waist circumference (cm)	85.8	86.3	88.4††	0.000
Systolic blood pressure (mmHg)	122	123	125††	0.015
Diastolic blood pressure (mmHg)	79	79	80	0.113
T-CHO (mg/dl)	204	202	199††	0.006
HDL-C (mg/dl)	58	57	54††	0.000
LDL-C (mg/dl)	128	127	125	0.194
TG (The median) (mg/dl)	148	145	159	0.188
HbA1c (%)	5.4	5.5	5.5	0.018
Number with MetS (%)	24.4	25.6	34.1	0.000□
Percentage taking medication for hypertension (%)	21.4	21.8	25.5	0.251□
Percentage taking medication for abnormal serum lipids (%)	12.9	10	10.3	0.064□
Percentage taking medication for diabetes mellitus (%)	5.8	5.3	6.6	0.620□
60–74 yrs old	**Group 1 <300 g/day**	**Group 2 300–450 g/day**	**Group 3 >450 g/day**	**P value**
Number of people	472	464	120	
Age	64	64	65††	0.013
BMI (kg/m^2)	23.7	23.7	23.6	0.925
Body fat (%)	21.9	21.7	21	0.190
Waist circumference (cm)	85.4	84.8	84.8	0.459
Systolic blood pressure (mmHg)	129	128	130	0.539
Diastolic blood pressure (mmHg)	79	78	79	0.357
T-CHO (mg/dl)	199	199	190††	0.013
HDL-C (mg/dl)	58	57	56	0.366
LDL-C (mg/dl)	124	124	118	0.105
TG (The median) (mg/dl)	133	132	125	0.739
HbA1c (%)	5.5	5.5	5.4	0.220
Number with MetS (%)	27.8	25.4	18.3	0.340□
Percentage taking medication for hypertension (%)	35.8	38.8	33.3	0.447□
Percentage taking medication for abnormal serum lipids (%)	11.9	15.3	8.3	0.081□
Percentage taking medication for diabetes mellitus (%)	11	8	3.3	0.021□

† There is a statistically significant difference between Group 1 and Group 2 at a P value of 0.05 or less. †† There is a statistically significant difference between Group 1 and Group 3 at a P value of 0.05 or less. □ Boxes (□) indicate results using the Chi-square test.

men (24.6%) in group 2 and 227 men (28.7%) in group 3 had MetS; in the 40–49 age range, 206 men (18.4%) in group 1, 185 men (22.8%) in group 2 and 86 men (26.9%) in group 3 had MetS; and in the 50–59 age bracket, 326 men (24.4%) in group 1,282 men (25.6%) in group 2 and 119 men (34.1%) in group 3 had the syndrome. In the 60–74 age bracket, 131 men (27.8%) in group 1,118 men (25.4%) in group 2 and 22 men (18.3%) in group 3 had MetS. A Chi-square test showed that the prevalence of MetS was significantly different between the three groups. This analysis showed that in men aged between 40–59 yrs, the prevalence of MetS tended to increase from group 1 to group 3, whereas in men aged between 60–74 yrs, the prevalence tended to decrease with increased intake of rice.

Comparison of subjects taking medication for hypertension, dyslipidemia and diabetes mellitus in the three rice intake groups, stratified according to age

Of the 2,254 men aged 40–49 yrs, 229 (10.2%) were taking antihypertensive medication, 136 (6.0%) were taking antihyperlipidemic medication and 76 (3.4%) were injecting insulin and/or taking medication for diabetes mellitus. The corresponding figures in the 2,786 men aged 50–59 yrs were 615 (22.1%) taking antihypertensives, 318 (11.4%) taking antihyperlipidemic medication and 159 (3.4%) taking anti-diabetes medication. Similarly, of the 1,056 men in the 60–74 age bracket, 389 (36.8%) were taking antihypertensives, 137 (13.0%) were taking antihyperlipidemic medication, and 93 (8.8%) were taking anti-diabetic medication.

We also compared the number of subjects taking medications in the three rice intake groups, stratified by age. The numbers of subjects taking antihypertensive medication in the 40–49 age range were 115 (10.2%), 84 (10.4%) and 30 (9.3%) in groups 1, 2, and 3, respectively; in the 50–59 age range, the numbers were 286 (21.4%), 240 (21.8%), and 89 (25.5%), respectively; and in the 60–74 age range, the numbers were 169 (35.8%), 180 (38.8%), and 40 (33.3%), respectively.

The numbers of subjects taking antihyperlipidemic medication in groups 1, 2 and 3, respectively, were 59 (5.3%), 55 (6.8%), and 22 (6.9%) in the 40–49 age bracket; 172 (12.9%), 110 (10.0%), and 36 (10.3%) in the 50–59 age bracket; and 56 (11.9%), 71 (15.3%) and 10 (8.3%) in the 60–74 age bracket.

The numbers of subjects injecting insulin and/or taking medication for diabetes mellitus in groups 1, 2 and 3, respectively, were 32 (2.9%), 27 (3.3%) and 17 (5.3%) in the 40–49 age bracket; 78 (5.8%), 58 (5.3%) and 23 (6.6%) in the 50–59 age bracket; and 52 (11.0%), 37 (8.0%) and 4 (3.3%) in the 60–74 age bracket.

This analysis showed that the percentage of men taking medication for hypertension, hyperlipidemia or diabetes mellitus increased with age. The analysis also indicated that the percentage of men injecting insulin and/or taking medication for diabetes mellitus declined significantly as intake of rice decreased.

Comparison of rice intake and quantitative non-rice food intake between the three rice intake groups (Table 2)

The following food intakes were significantly different between groups 1, 2 and 3: weekly egg intake and daily milk intake in men aged 40–49 yrs and weekly egg intake, daily milk intake, daily sugared beverage intake and weekly alcoholic beverage intake in men aged 50–59 yrs. In men aged 60–74 yrs, there were no significant differences in intake of non-rice foods between the three rice intake groups.

A second statistical test, Tukey's multiple comparison test, was performed for four factors (weekly egg intake, daily milk intake, daily sugared beverage intake and weekly alcoholic beverage intake) in which one-way analysis of variance showed significant differences between the rice intake groups. In this test, group 1 was compared with groups 2 and 3.

In men aged 40–49 yrs, weekly egg intake was significantly different in both groups 2 and 3 compared with group 1, while in men aged 50–59 yrs, weekly egg intake, daily milk intake and weekly alcoholic beverage intake were significantly different in groups 2 and 3 relative to group 1.

In the 40–49 age bracket, daily sugared beverage and weekly alcoholic beverage intake were significantly different only between rice intake groups 1 and 2, while in the 50–59 age bracket, daily sugared beverage intake was significantly different only in groups 1 and 2.

Relationship between the three rice intake groups and categorized (nonquantitative) food intake and lifestyle factors (Table 3)

The following items showed significant differences between the three rice intake groups: level of daily physical activity; frequency of checking body weight; living arrangements; gaining 10 kg or more of body weight since the age of 20; eating quickly compared with other people; going to bed within 2 hours of having dinner, snacking after dinner or skipping breakfast 3 or more times per week; and eating 200 g or more of fruit per day.

In men aged 40–49 yrs, living arrangements (alone, as a couple or other), level of daily physical activity, frequency of checking body weight, gaining 10 kg or more of body weight since the age of 20, eating quickly compared with other people and skipping breakfast 3 or more times per week were significantly different between the 3 rice intake groups. In men aged 50–59 yrs, the same variables plus snacking after dinner 3 or more times per week were

Table 2 Comparison of rice intake and non-rice food intake in the three rice intake groups

40–49 yrs old	Group 1 <300 g/day	Group 2 300–450 g/day	Group 3 >450 g/day	P value
Number of people	1122	810	321	
Egg intake per week (g)	139	145†	171††	0.000
Milk intake per day (g)	116	110	122	0.004
Sugared beverages per day (Bottle)	1.02	0.98†	1.04	0.015
Alcoholic beverages per week (180 ml)	7.7	7.4†	7.1	0.006
50–59 yrs old	**Group 1 <300 g/day**	**Group 2 300–450 g/day**	**Group 3 >450 g/day**	**P value**
Number of people	1335	1102	349	
Egg intake per week (g)	139	145†	160††	0.000
Milk intake per day (g)	111	109†	94††	0.000
Sugared beverages per day (Bottle)	0.94	0.86†	0.91	0.001
Alcoholic beverages per week (180 ml)	7.9	7.4†	7.6††	0.000
60–74 yrs old	**Group 1 <300 g/day**	**Group 2 300–450 g/day**	**Group 3 >450 g/day**	**P value**
Number of people	472	464	120	
Egg intake per week (g)	146	141	137	0.115
Milk intake per day (g)	108	154	112	0.889
Sugared beverages per day (Bottle)	0.79	0.75	0.85	0.480
Alcoholic beverages per week (180 ml)	7.7	7.5	7.8	0.169

† There is a statistically significant difference between Group1 and Group 2 at a P value of 0.05 or less. †† There is a statistically significant difference between Group1 and Group 3 at a P value of 0.05 or less.

significantly different between the 3 rice intake groups. In the 60–74 age bracket, consuming 200 g or more of fruit per day, level of daily physical activity, and snacking after dinner 3 or more times per week were significantly different between the 3 rice intake groups.

Odds ratios for rice intake in people with and without MetS in each of the three age brackets (Table 4)

In all three age brackets, rice intake was related strongly to the incidence of MetS. In two-factor logistic model 1, which excluded age as a possible confounding factor for MetS risk, we obtained the following results: in men aged 40–49 yrs, the odds ratio was significantly different in rice intake groups 2 (1.308 times higher) and 3 (1.646 times higher) compared with group 1; in men aged 50–59 yrs, the odds ratio was significantly different in group 3 (1.602 times higher) compared with group 1; and in men aged 60–74 yrs, the odds ratio was significantly different in group 3 (0.571 times lower) compared with group 1.

In multi-logistic model 2, which excluded all factors considered confounding effects for MetS risk, we obtained the following results: in men aged 40–49 yrs, the odds ratio was significantly different in rice intake group 3 (1.461 times higher) compared with group 1, and in men aged 50–59 yrs, the odds ratio was significantly different in group 3 (1.501 times higher) compared with group 1; on the other hand, in men aged 60–74 yrs, there was no significant difference in odds ratio between the three rice intake groups.

Discussion

This study provides information on the relationship between rice intake, lifestyle factors and MetS in men aged 40 to 75 yrs who underwent a complete medical examination *(Ningen Dock)* between April 2008 and November 2010. To investigate the cause of MetS, our study focused on overeating of rice and analyzed the relationship between rice intake and incidence of MetS in men, stratified according to age.

The men were first classified as to whether or not they had MetS, initially using waist circumference and then by precise diagnosis based on the formal Japanese criteria including factors such as hypertension and diabetes mellitus.

In men aged 40–49 and 50–59 yrs, BMI, waist circumference and prevalence of MetS correlated significantly with the level of rice consumption. In contrast, in men aged 60–74 yrs, BMI, waist circumference, and prevalence of MetS correlated negatively with rice consumption.

Logistic model 1 used age as a confounding factor to exclude dummy effects based on the possibility that younger people consume a greater volume of rice than older people.

Table 3 Relationship between the three rice intake groups and (1) non-rice food intake by category, and (2) lifestyle environmental factors

40–49 yrs old	Group 1 <300 g/day	Group 2 300–450 g/day	Group 3 >450 g/day	P value
Number of people	1122	810	321	
Smoking habits (%)	43.0	41.9	43.0	0.862
Gain of ≥ 10 kg in body weight since the age of 20 (%)	52.8	57.7	62.9	0.003
Exercise regularly for ≥30 minutes at least twice a week for at least 1 yr (%)	19.3	18.6	19.0	0.928
Walking or carrying out other similar physical activities for ≥ 1 hour per day (%)	21.5	24.0	27.1	0.088
Faster walking compared with the pace of walking in the same generation (%)	40.8	41.9	40.8	0.892
Gain of ≥ 4 kg in body weight per yr (%)	35.2	37.3	39.9	0.274
Eating quickly compared with other people (%)	43.2	47.0	56.1	0.000
Having dinner within 2 hours of going to bed ≥ 3 times per week (%)	44.2	43.6	46.1	0.742
Snacking ≥ 3 times per week (%)	22.5	22.5	25.2	0.549
Skipping breakfast ≥ 3 times per week (%)	28.2	19.0	22.4	0.000
Sufficient sleep (%)	57.5	58.6	54.8	0.504
Family structure alone (%)	11.2	5.4	4.0	0.000
Family structure couple only (%)	9.3	9.5	4.4	0.013
Family structure other style (%)	79.6	85.1	91.6	0.000
Mild level of daily physical activity (%)	63.4	57.5	49.8	0.000
High level of daily physical activity (%)	8.3	8.8	15.9	0.000
Frequency of checking body weight (%)	61.3	60.1	67.3	0.060
Eating ≥ 200 g of fruit per day (%)	5.8	5.8	7.8	0.659
Daily snacking habit (%)	13.5	15.1	14.0	0.624
50–59 yrs old	**Group 1 <300 g/day**	**Group 2 300–450 g/day**	**Group 3 >450 g/day**	**P value**
Number of people	1335	1102	349	
Smoking habits (%)	41.7	38.8	43.6	0.190
Gain of ≥ 10 kg in body weight since the age of 20 (%)	51.0	56.2	58.7	0.007
Exercise regularly for ≥30 minutes at least twice a week for at least 1 yr (%)	23.0	21.7	19.5	0.347
Walking or carrying out other similar physical activities for ≥ 1 hour per day (%)	21.9	20.8	22.9	0.652
Faster walking compared with the pace of walking in the same generation (%)	43.5	43.4	39.0	0.285
Gain of ≥ 4 kg in body weight per yr (%)	28.6	25.5	28.9	0.182
Eating quickly compared with other people (%)	38.2	38.5	48.1	0.012
Having dinner within 2 hours of going to bed ≥ 3 times per week (%)	35.7	31.0	34.7	0.051
Snacking ≥ 3 times per week (%)	16.0	19.2	20.3	0.045
Skipping breakfast ≥ 3 times per week (%)	17.3	11.6	8.0	0.000
Sufficient sleep (%)	63.9	66.2	66.5	0.431
Family structure alone (%)	9.8	5.4	3.7	0.000
Family structure couple only (%)	26.7	23.0	24.6	0.120
Family structure other style (%)	63.6	71.6	71.6	0.000
Mild level of daily physical activity (%)	67.9	61.5	49.3	0.000
High level of daily physical activity (%)	7.0	9.0	16.9	0.000
Frequency of checking body weight (%)	54.1	63.2	67.9	0.000
Eating ≥ 200 g of fruit per day (%)	11.2	8.7	8.6	0.006
Daily snacking habit (%)	11.3	12.7	15.5	0.169
60–74 yrs old	**Group 1 <300 g/day**	**Group 2 300–450 g/day**	**Group 3 >450 g/day**	**P value**
Number of people	472	464	120	
Smoking habits (%)	28.0	26.7	21.7	0.379
Gain of ≥ 10 kg in body weight since the age of 20 (%)	46.8	45.3	35.8	0.095
Exercise regularly for ≥30 minutes at least twice a week for at least 1 yr (%)	41.5	37.5	33.3	0.191
Walking or carrying out other similar physical activities for ≥ 1 hour per day (%)	39.6	39.2	43.3	0.707
Faster walking compared with the pace of walking in the same generation (%)	46.2	50.6	41.7	0.150
Gain of ≥ 4 kg in body weight per yr (%)	25.0	22.6	17.5	0.209
Eating quickly compared with other people (%)	33.7	34.3	35.8	0.816
Having dinner within 2 hours of going to bed ≥ 3 times per week (%)	18.0	19.0	33.3	0.001
Snacking ≥ 3 times per week (%)	15.7	17.0	13.3	0.596
Skipping breakfast ≥ 3 times per week (%)	5.9	5.2	6.7	0.780
Sufficient sleep (%)	77.3	77.4	82.5	0.440
Family structure alone (%)	4.2	5.0	0.8	0.131
Family structure couple only (%)	48.5	43.8	44.2	0.315
Family structure other style (%)	47.1	51.3	55.0	0.218
Mild level of daily physical activity (%)	54.7	39.0	25.8	0.000
High level of daily physical activity (%)	8.1	16.8	35.0	0.000
Frequency of checking body weight (%)	49.2	50.0	55.8	0.255
Eating ≥ 200 g of fruit per day (%)	20.6	20.5	24.2	0.065
Daily snacking habit (%)	16.5	20.9	17.5	0.322

All statistically significant differences in the Table 3 were found by the Chi-square test.

Table 4 The adjusted odds ratio of confounding factors in metabolic syndrome in the three age brackets (40–49, 50–59, 60–74)

		Mode analysis 1[*1]		Mode analysis 2 [*2]	
		Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
40–49 yrs old					
Group 1	<300 g/day	1.000		1.000	
Group 2	300–450 g/day	1.308	(1.046-1.636)*	1.240	(0.975-1.578)
Group 3	>450 g/day	1.646	(1.231-2.201)*	1.461	(1.065-2.005)*
50–59 yrs old					
Group 1	<300 g/day	1.000		1.000	
Group 2	300–450 g/day	1.064	(0.885-1.279)	1.004	(0.82-1.228)
Group 3	>450 g/day	1.602	(1.242-2.066)*	1.501	(1.129-1.996)*
60–74 yrs old					
Group 1	<300 g/day	1.000		1.000	
Group 2	300–450 g/day	0.876	(0.655-1.173)	0.886	(0.650-1.207)
Group 3	>450 g/day	0.571	(0.344-0.947)*	0.625	(0.362-1.080)

[*1] Logistic Model 1 shows the odds ratio adjusted by age. [*2] Logistic Model 2 shows the odds ratio adjusted by age and other confounding factors such as (1) egg intake per week, (2) vegetable intake per day, (3) milk intake per day, (4) sugary beverage intake per day, (5) alcoholic beverage intake per week, (6) family structure, (7) mild level of daily physical activity, (8) checking body weight less than 3 times per week, (9) a gain of ≥10 kg in body weight since the age of 20, (10) eating quickly compared with other people, (11) having dinner within 2 hours of going to bed more than 3 times a week, (12) snacking after dinner 3 or more times per week and (13) skipping breakfast 3 or more times per week.
The icon "*" means P values ≤ 5% implying statistically significant differences.

In logistic model 2, BMI, percentage body fat, waist circumference, systolic blood pressure, HDL-C and HbA1c were not included as confounding factors, as they comprise the diagnostic criteria for MetS, despite one-way analysis of variance showing these factors were significantly different between the three rice intake groups.

We also did not designate T-CHO as a confounding factor, as it includes HDL-C, LDL-C, and TG. Percentage body fat was also not included as a confounding factor, as it correlates strongly with BMI.

In men aged 40–49 and 50–59 yrs, the adjusted odds ratio for each factor in both logistic models 1 and 2 showed a significant increase in MetS in groups with higher rice intake. In particular, in the 40–49 age bracket, the greater the volume of rice consumed, the stronger the relationship with MetS. However, in logistic model 1, the odds ratio for MetS decreased significantly with increased rice intake in men aged 60–74 yrs.

Recent studies have reported that high levels of carbohydrate intake increase the risk of type 2 diabetes mellitus. Nanri *et al.*[7)] showed in Japanese women and men aged 45–75 yrs who did not engage in physical labor, that the risk of type 2 diabetes mellitus correlated with the amount of rice consumption. Possible reasons for this relationship are the facts that much of the dietary fiber and magnesium ions, which have a protective effect against type 2 diabetes mellitus, are lost when white rice is refined, and white rice has a high glycemic index, an indicator of the ability of a food to increase blood sugar levels.

Nanri *et al.*[7)] reported that even people who carry out physical labor or engage in vigorous exercise for more than an hour each day and who consume large volumes of rice, need to maintain a balance between energy intake and consumption to avoid weight gain and increased risk of developing type 2 diabetes mellitus. Therefore, Nanri *et al.*[7)] suggested that in order to prevent the development of type 2 diabetes mellitus, Japanese people should increase their daily physical activity and eat a variety of cereals in order to avoid the rapid increase in blood sugar that occurs after eating white rice.

Hee Jung *et al.*[8)] reported that diet therapy based on reducing the size of the bowl in which rice is served was effective for decreasing both rice and total energy intake in obese Korean men with type 2 diabetes mellitus. These studies by Nanri *et al.*[7)] and Hee Jung *et al.*[8)] suggest that high levels of rice intake can cause central obesity, which in turn can lead to MetS.

It is well established that MetS leads to abnormal glucose metabolism. Kadowaki *et al.*[9)] have described the detailed pathogenesis of diabetes mellitus during the development of worsening MetS. Obesity is a state of fat cell hypertrophy that develops when energy accumulation exceeds energy consumption. Kadowaki *et al.*[9)] demonstrated that obesity strongly promotes the development of diabetes mellitus, with the risk of diabetes being four times higher in individuals with a BMI of 25 kg/m^2 or greater compared to those with a normal body weight and 10 times higher in individuals whose body weight is 30% or more greater than standard body weight.

Another epidemiological study[10] reported that as Japanese people have low levels of insulin secretion, even mild obesity can promote the destruction of pancreatic β-cells, resulting in the development of diabetes mellitus. Hypertrophic fat cells oversecrete cytokines such as TNF-α and resistin as well as free fatty acids (FFAs). These cytokines and FFAs cause insulin resistance in muscle and the liver, resulting in diabetes mellitus, abnormal serum lipid levels and hypertension.

A Molecular biological study[9] reported that adiponectin has an inhibitory effect on arteriosclerosis, with central obesity leading to a decrease in adiponectin secretion. Accordingly, MetS pathogenesis resulting from central obesity can be explained by increased secretion of inflammatory adipocytokines and impaired adiponectin secretion.

As expected, in the 40–49 and 50–59 age groups, rice intake correlated positively with the incidence of MetS; whereas in the 60–74 age group, the opposite relationship was observed. In men aged 60–74 yrs, BMI, waist circumference and prevalence of MetS actually decreased with increasing rice consumption. In the group that consumed 300 g or less of rice per day, the highest rate of MetS occurred in men aged 60–74 yrs. However, this age bracket had the lowest rate of MetS in the group consuming at least 450 g of rice per day. We suggest that this finding may be due to the fact that older individuals have more opportunities to undergo medical examinations and receive dietary advice, and as a result, this age bracket contained the highest percentage of men who ate rice three times a day in reasonable quantities. We also consider that these results are related to the levels of physical exercise, as we showed the percentage of participants who exercised regularly for 30 minutes or more at least twice a week for at least one year was highest in men aged 60–74 yrs. Furthermore, the percentage of participants who walked or participated in similar intensity physical activities for an hour or more each day was highest in the 60–74 age bracket.

It is suggested that as men aged 40–59 yrs consider themselves to be in good health, they may not be willing to make lifestyle changes such as decreasing rice intake and increasing exercise. In addition, as men aged 60–74 yrs tend to suffer from lifestyle-related disorders such as hypertension and diabetes mellitus, they have more opportunities to receive health counseling and nutritional instruction from public health nurses during annual medical examinations. This health and nutritional guidance generates a "sense of health" and leads men in this age bracket to be more likely to take regular medications for hypertension, diabetes mellitus and abnormal serum lipid levels. In other words, health counseling can cause behavioral changes leading to decreased rice intake.

Fujiuchi *et al.*[11] reported that a high percentage of elderly men are very motivated to maintain good health. Miyata *et al.*[12] also suggested that people are able to make lifestyle changes if they recognize that their diet and exercise habits influence their health and that people who are able to carry out health-related lifestyle changes acquire a level of health consciousness. According to Miyata *et al.*[12], the acquisition of health consciousness is related to a strong sense of community and quality of life. One report[13] suggested that follow-up meetings after annual medical checkups by either public health nurses or nutritionists could have a positive impact on individuals by raising awareness of their health problems. Another report[14] suggested that programs under the National Health Promotion Law, aimed at improving eating and exercise habits in obese and overweight individuals, may lead to behavioral changes resulting in lower calorie diets, greater physical activity, and reduced body weight.

It has been reported that while the percentage of adolescents who consume more bread or noodles than rice has increased, the majority of people aged 50 yrs and older eat rice three times each day and have a well-balanced diet[15]. In recent years, the Westernization of Japanese eating habits has been identified as the primary cause of increased intake of dietary fat, which in turn has led to an increase in the number of Japanese people with central obesity. Prior to the U.S. occupation (1945–1952)[16], the Japanese diet did not contain large quantities of meat and consisted primarily of rice, vegetables and fish.

The 2008 National Health and Nutrition Examination Survey[6] indicated that 17.4% of men and 25.0% of women regularly consume food with a high fat content (30% fat or greater) compared with only 6% of Japanese people in 1945. The volume of rice intake in Japan has increased by approximately 100 g per day since 1945, rising from a total of 248.3 g per day in the 1945 survey to 341.6 g per day in the 2008 survey. Furthermore, the prevalence of motor vehicles, elevators, and escalators has contributed to a lack of exercise in Japanese people. However, the consumption of fatty food is not the only cause of MetS, with overeating, eating less than two hours before going to bed, and snacking also being contributing factors.

The 2008 National Health and Nutrition Examination Survey[6] revealed that 25.3% of men and 10.6% of women older than 20 yrs were suspected of having MetS and that 21.9% of men and 8.3% of women were likely to develop the condition in the future. Improvement in eating habits and increased physical exercise are needed to combat the incidence of MetS.

Study limitations

The main limitation of this study was that we did not measure total dietary energy intake. Further detailed research is therefore necessary to assess energy intake from macronutrients other than carbohydrates, namely, from protein and fat. A further limitation of this study was that we were unable to clarify the relationship between rice intake and the incidence of MetS.

Conclusions

Our study revealed that there was a strong relationship between rice intake and the incidence of MetS in men aged 40–59 yrs. However, in men aged 60–74 yrs, there was a mild inverse relationship between rice intake and MetS.

The percentage of participants taking medication for hypertension, diabetes mellitus or dyslipidemia was highest in the 60–74 age bracket. In people aged 60 yrs or older, the key to treating MetS is through health and nutrition counseling and managing the condition with medication. However, in all age groups, it is necessary to make an effort to establish behavioral changes that will lead to a healthier diet and lifestyle.

According to the Japanese dietary standards, it is important to educate people on the fact that energy needs vary with age, and that this should be taken into account when balancing calorie intake.

Acknowledgments

The authors are greatly indebted and grateful to the participants who took part in our survey.

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