Original Article

Rice intake, weight change and risk of the metabolic syndrome development among Chinese adults: the Jiangsu Nutrition Study (JIN)

Zumin Shi MD, PhD[1,2], Anne W Taylor PhD[2], Gang Hu MD, PhD[3], Tiffany Gill PhD[2], Gary A Wittert MBBch, MD[2]

[1] *Department of Nutrition and Foodborne Disease Prevention, Jiangsu Provincial Centre for Disease Control and Prevention, Nanjing, China*
[2] *Discipline of Medicine, University of Adelaide, Frome Rd, Adelaide, Australia*
[3] *Chronic Disease Epidemiology Laboratory, Pennington Biomedical Research Centre, Louisiana State University System, Baton Rouge, LA, USA*

Objectives: To examine the association between rice intake, staple food patterns (measured by percentage of rice in staple food (PRS)), weight change and the risk of the metabolic syndrome development. Methods: We followed 1231 adults, aged 20 and older, from 2002 to 2007. Food intake was assessed using a food frequency questionnaire. Body weight, height, waist circumference, blood pressure and fasting plasma glucose and lipids were measured. The metabolic syndrome was defined according to the International Diabetes Federation definition. Results: Rice consumption of ≥401 g/day was associated with less weight gain (-2.08 kg, 95%CI: -2.75, -1.41, $p<0.001$), and 42% less risk of hypertension, as compared to rice consumption of <200 g/day ($p=0.024$). A strong linear association between rice intake and hyperglycemia was found: the odd ratios for incident hyperglycemia across rice intake <200, 201-400, ≥401 g/day were: 1, 1.96, 2.50 (95%CI: 1.37, 4.57) (*p* for trend 0.005). A positive association between rice intake and incident abnormal high-density lipoprotein was observed. There was no association between rice intake and incident high triglycerides. Every 10% increase in PRS was associated with a 0.28 kg less in weight gain, 22% increase in hyperglycemia risk and 9% decrease in hypertension risk. Rice intake and PRS were not associated with the risk of the metabolic syndrome. Conclusion: Rice intake and PRS were inversely associated with weight gain, and PRS was inversely associated with hypertension, but positively associated with fasting blood glucose elevation. No association between rice intake and PRS with the metabolic syndrome was found.

Key Words: rice intake, weight change, the metabolic syndrome, Chinese, cohort study

INTRODUCTION

The metabolic syndrome is characterized by the clustering of abdominal obesity, raised blood pressure, elevated fasting plasma glucose concentration, and dyslipidemia.[1,2] The syndrome is associated with the development of diabetes and cardiovascular diseases.[3-8] Obesity and insulin resistance have been proposed as an important mechanism underlying the metabolic syndrome.[2]

Epidemiologic and experimental studies suggest that diet could be important for determining the metabolic syndrome.[9,10] Consumption of whole grains, fruit and vegetables are related to a lower risk of the metabolic syndrome.[11] A low fiber Western dietary pattern is related to an increased risk of the metabolic syndrome.[12]

There has been a rapid increase in the prevalence of obesity in China during the past decade,[13] associated with changes in diet and physical activity.[14] The reported prevalence of the metabolic syndrome ranges from 3.2 to 17.8% in different studies in China[15-17] depending on urban–rural residency and socio-economic status. The prevalence rates, while lower than in Western populations, are likely to increase in the future; and accordingly, it is important to understand the patterns of dietary change and associations with obesity and cardio-metabolic risk in order to develop clear public health recommendations. Generally, the Chinese diet is characterized by a high intake of grain, vegetables and other plant foods, and thus the intake of complex carbohydrates and fiber is high. [18]

Rice is the main staple food for more than half of the world's population, mostly in Asian countries. Rice has high glycemic index (GI) and is related to the risk of type 2 diabetes mellitus.[19]

Corresponding Author: Dr Zumin Shi, Department of Nutrition and Foodborne Disease Prevention, Jiangsu Provincial Centre for Disease Control and Prevention, 172 Jiangsu Road, Nanjing 210009, China. Or, Discipline of Medicine, University of Adelaide, Adelaide SA 5000, Australia.
Tel: +61 8 8313 1188; Fax: +61 8 8313 1228
Email: zumins@vip.sina.com
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A high GI or high glycemic load diet is also related to elevation of plasma triglycerides (TG) and HDL levels.[20,21] Rice has been shown to have an anti-hypertensive effect in animals,[22] and early in the 1940's, a rice diet (including rice, sugar, fruit, and fruit juices) was used by Walter Kempner to treat hypertension in patients with chronic glomerulonephritis.[23] It is not, however, known whether there is any relationship between rice consumption and the incidence of cardiovascular risk factors at a population level. We therefore prospectively evaluated the relationship between rice consumption, weight gain and the metabolic syndrome, as defined by the International Diabetes Federation (IDF) in Chinese adults.

RESEARCH DESIGN AND METHODS

Sample

The Jiangsu Nutrition Study (JIN) is an ongoing cohort study investigating the association between nutrition and other factors with the risk of non-communicable chronic disease.[24-26] The sample was based on a subsample of the Chinese National Nutrition and Health Survey representing Jiangsu province, and the year 2002 was used as a base line. The rural sample was selected from six counties (Jiangyin, Taichang, Shuining, Jurong, Sihong and Haimen). From each of the six counties, three smaller towns were randomly selected. The urban sample was selected from the capital cities of the two prefectures, Nanjing and Xuzhou; and from each capital city three streets were randomly selected. The six counties and the two prefectures represented a geographically and economically diverse population. In each town/street, two villages/ neighborhoods were randomly selected, and 90 households were further randomly selected from each village/ neighborhood. All members of the households were invited to participate in the study. In addition, one third of the households were interviewed on dietary intake, and all family members, aged three years and older, from these households were invited to provide fasting blood samples. Written consents were obtained from all the participants. The study was approved by the ethical committee of Jiangsu Provincial Centre for Disease Control and Prevention.

In 2002, height, weight, and dietary information was obtained from 2849 adults, aged 20 and above, and plasma glucose was measured in fasting blood. In 2007, an attempt to contact all original participants was made but some had either moved to other cities for temporary work or moved to other streets within the urban area. Therefore of the original 2849 participants, 1682 were identified for follow-up, 1492 (88.7%) actually participated in the follow-up interview, 190 participants refused to participate, and height and weight were obtained in 1282 (76.2%) of them (210 participants completed interview at home but missed the measurements in the clinic). For analysis of weight change, we excluded participants who had extreme values of weight change of more than 20 kg (n=11), and those who had known diabetes, stroke, or cancer at baseline (n=40). The final sample in the study for weight change consisted of 510 men and 721 women. Compared with the retained participants (n=1682), those lost to follow up (n=1167) were generally younger, with a higher BMI and waist circumference, but there were no differences in gender, or energy intake (Table 1). For analysis of the metabolic syndrome, we only excluded those who had stroke and cancer at baseline. In total, 1102 participants had measurements of all of the components of the metabolic syndrome in both surveys.

Data collection and measurements

Participants were interviewed at their homes by health workers using a standard questionnaire.[25] All health workers were intensively trained.

Measurements

Blood pressure and anthropometric measurements were obtained by trained and certified field workers using standard protocols and techniques. Two blood pressure measurements were obtained with the participant in the seated position after five minutes of rest. Body weight was measured in light indoor clothing without shoes to the nearest 100 g. Height was measured without shoes to the nearest mm, using a wall mounted stadiometer. Waist circumference was measured midway between the inferior margin of the last rib and the crest of the ilium, in the mid-axillary line, in a horizontal plane. Overnight fasting blood specimens were obtained early in the morning at the study sites for measurement of serum lipids and plasma glucose during three days of follow up. Concentrations of total cholesterol, high-density lipoprotein (HDL)-cholesterol, and triglycerides were assessed enzymatically with commercially available reagents using Automatic OLYMPUS Biochemical Analyzer (Olympus, Tokyo, Japan).

The metabolic syndrome

The metabolic syndrome was defined by the International Diabetes Federation (IDF) criteria.[1] Affected individuals meet the criterion if their waist circumference (WC) was ≥90 cm in men or ≥80 cm in women, plus two or more of

Table 1. Sample characteristics between those retained and those lost to follow up

	Original sample (n=2849)	Lost to follow up (n=1167)	Retained (n=1682)	*p*†	Included in weight change analysis (n=1231)	*p*‡
Age, years (mean, SD)	47.0 (14.5)	45.3 (15.4)	48.2 (13.7)	<0.001	49.0 (13.2)	<0.001
BMI, kg/m^2 (mean, SD)	23.5 (3.5)	23.7 (3.6)	23.4 (3.4)	0.012	23.4 (3.3)	0.070
Waist circumference (cm), (mean, SD)	79.3 (10.1)	79.9 (10.5)	78.8 (9.8)	0.004	78.6 (9.5)	0.002
Energy, kcal (mean, SD)	2351 (687)	2355 (723)	2348 (662)	0.785	2332 (645)	0.218
Men (%)	45.9	46.1	45.8	<0.865	41.4	<0.001

† comparing lost to follow up with retained.
‡Comparing those included in the weight change analysis with lost to follow up/excluded from the analysis.

the following four factors: triglyceride level ≥150 mg/dL (1.7 mmol/L) or specific treatment for this lipid abnormality; HDL-C <40 mg/dL (1.03 mmol/L) in men or <50 mg/dL (1.29 mmol/L) in women or specific treatment for this lipid abnormality; blood pressure ≥130/85 mmHg or using antihypertensive treatment; and fasting plasma glucose (FPG) ≥100 mg/dL (5.6 mmol/L) or previously diagnosed type 2 diabetes.

Dietary measurements

Diet during the past year was determined by a series of detailed questions about usual frequency and quantity of intake of 33 food groups and beverages including two main staple foods (rice and wheat flour).[25,26] The food frequency questionnaire used has been validated [27,28] and reported to be a useful method for the collection of individual food consumption information in face-to-face interviews, but not in self-administered surveys, due to the current educational level of the majority of the Chinese population. In the region, rice and wheat flour were the main staple foods. In the analysis, staple food patterns were measured as percentage of rice in staple foods (PRS, PRS=rice intake/(rice intake + wheat flour intake)).

Nutrient and vegetable oil intakes were measured both by weighing and by consecutive individual three day food records, and this was checked by the health workers during the survey. Food consumption data were analyzed using the Chinese Food Composition Table [29].

Other factors

Cigarette smoking was assessed by asking the frequency of daily cigarette smoking. Alcohol consumption was assessed by asking the frequency and amount of alcohol/wine intake. Questions on daily commuting were combined into three categories: 1) using motorized transportation, or no work (0 minute of walking or cycling); 2) walking or bicycling 1-29 minutes; and 3) walking or bicycling for ≥30 minutes. Daily leisure time physical activity was classified into three categories: 0, 1-29, and ≥30 minutes. Education was categorized into three categories, based on a six education levels in the questionnaire: 'Low': illiteracy, primary school; 'Medium': junior middle school; 'High': high middle school or higher. Occupation was recoded into manual or non-manual based on a question with 12 occupational categories.

Statistical analyses

Rice intake was divided into three groups: ≤200 g, 201-400 g, ≥401 g/day. The grouping of rice intake is based on serving size ('rice bowls') to facilitate interpretation. Chi-square test was used to compare the difference between categorical variables, and ANOVA was used to compare differences in continuous variables among groups. Multilevel mixed-effects linear regression (xtmixed in STATA) was used to determine the association between rice intake, PRS and weight change between baseline and follow up adjusted for age, education, occupation, active commuting, leisure time physical activity, smoking, alcohol drinking, and energy intake. Multilevel logistic regression (xtmelogit in STATA) was used to assess the association between rice intake, PRS and the development of the metabolic syndrome and its individual components. Household cluster was adjusted in these multivariate models. To assess the association between rice intake, PRS and the risk of individual components of the metabolic syndrome, we excluded those with corresponding abnormal component at baseline. When assessing the association between rice intake and the risk of the metabolic syndrome, we only excluded those with the metabolic syndrome at baseline. We tested for linear trend across categories of rice intake by assigning each participant the median value for the category and modeling this value as a continuous variable. Percentage of rice in staple food was used as continuous variable in all analyses. All analyses were performed by using STATA 10 (Stata Corporation, College Station).

Table 2. Demographic and behaviour variables according to rice intake among Chinese adults

	Rice intake (g/day)			*p*
	0-200 (n=347)	201-400 (n=430)	≥401 (n=454)	
Men (%)	36.6	32.3	53.5	<0.001
Age, years (mean, SD)	47.5 (12.7)	50.4 (14.5)	49.1 (11.9)	0.008
BMI (kg/m^2)	23.7 (3.4)	23.1 (3.3)	23.4 (3.3)	0.040
Waist circumference, (cm) (mean, SD)	79.7 (9.8)	77.2 (9.5)	79.3 (9.4)	<0.001
Education (%)				
Low	55.0	50.9	53.5	
Medium	34.9	35.8	36.3	0.528
High	10.1	13.3	10.1	
Manual job (%)	52.8	41.4	60.4	<0.001
Active commuting (%)				
None	40.5	52.8	30.2	
1-30 minutes/day	39.7	43.3	59.7	<0.001
>30 minutes/day	19.8	4.0	10.1	
Leisure time physical activity (%)				
None	88.3	91.6	93.8	
1-30 minutes/day	5.9	4.0	3.5	0.063
>30 minutes/day	5.9	4.4	2.6	
Smoker (%)	23.5	21.9	34.8	<0.001
Alcohol drinker (%)	22.6	21.9	29.1	0.031

Table 3. Daily nutrient intakes (mean, SE) according to rice intake among Chinese adults

	Rice intake (g/day)			*p*
	0-200 (n=347)	201-400 (n=430)	≥401 (n=454)	
Energy (kcal) †	2286 (32)	2235 (29)	2450 (28)	<0.001
Fat (g) ‡	76.1 (1.3)	87.8 (1.2)	80.3 (1.2)	<0.001
Protein (g) ‡	72.3 (0.8)	73.6 (0.7)	71.3 (0.7)	0.178
Carbohydrate (g) ‡	329 (3.1)	300 (2.8)	324 (2.8)	<0.001
Fiber (g) ‡	12.7 (0.4)	9.7 (0.4)	9.0 (0.3)	<0.001
Iron (mg) ‡	27.5 (0.4)	24.3 (0.3)	23.4 (0.3)	<0.001
Zinc (mg) ‡	11.7 (0.1)	12.3 (0.1)	12.3 (0.1)	<0.001
Sodium (mg) ‡	6240 (217)	6837 (200)	7014 (196)	0.028
Potassium (mg) ‡	1681 (22.7)	1704 (20.1)	1649 (19.7)	0.230
Calcium (mg) ‡	422 (9.8)	457 (8.9)	422 (8.7)	0.009
Rice (g) †	114 (4)	305 (3)	494 (3)	<0.001
Wheat flour (g) †	266 (6)	38 (5)	15 (5)	<0.001
Vegetables (g) †	213 (8)	264 (7)	294 (7)	<0.001
Fruits (g) †	66 (5)	53 (4)	53 (4)	0.132
Animal foods (g) †	48 (3)	66 (3)	60 (3)	<0.001

† adjusted for age and sex
‡ adjusted for age, sex and energy intake

RESULTS

At baseline, there were significant differences in age, BMI, WC by rice intake levels (Table 2). The mean intake of rice was 321 g/day (SD 172). Overall, 28.6% of the participants had rice intake <200 g/day, while 36.9% of the participants had rice intake ≥401 g/day. The distribution of PRS was skewed with 9.8% of the participants having PRS below 10% and 51.2% above 90% (data not shown). Table 3 shows that rice intake was positively associated with the intake of energy, fat, zinc, sodium, animal foods and vegetables, but inversely associated with fiber, iron, and wheat flour intakes.

The mean 5-year weight gain among all participants was 0.8 kg (SD 4.7). Among the 1102 participants who had measurements of the metabolic syndrome components in both surveys, 167 (15.2%) had the metabolic syndrome at baseline, and 137 (14.7%) developed the metabolic syndrome during follow up.

An inverse association between rice consumption and weight change was found. In multivariable linear regression analysis, using rice intake ≤200 g as a reference (Table 4), participants with rice intake ≥401 g/day had a regression coefficient of -2.08 (95% confidence interval (CI): -2.75, -1.41, $p<0.001$) for weight gain, indicating significantly less weight gain. A 10% increase in PRS was associated with a 0.28 (-0.37, -0.19) decrease in weight gain. As the distribution of PRS is skewed, analyses were also undertaken with 1) those with PRS above 90% excluded: and 2) both those above 90% and the bottom 10% of PRS excluded. The associations between PRS and weight change were not altered (data not shown).

Rice intake was positively associated with the development of hyperglycemia (Table 5) in the multivariable model. Odds ratios (ORs) for incident hyperglycemia across rice intake (≤200, 101-200, 201-400, ≥401 g/day) were: 1, 1.96 (1.07-3.60), 2.50 (1.37-4.57) (*p* for trend 0.005). In the fully adjusted model, each 10% increase of PRS was associated with a 22% increase in the risk of hyperglycemia. An inverse association between rice intake and the risk of high blood pressure was observed. Compared with daily rice intake ≤200 g, rice intake ≥401 g was associated with 42% decrease in the risk of developing high blood pressure (p=0.024). Each 10% increase in PRS was associated with a 10% decrease of the risk of hypertension. A high intake of rice was associated with an increased risk of low HDL. The ORs (95%CI) for low HDL across rice intake ≤200, 201-400, ≥401 g/day were: 1, 1.48 (0.93-2.35) and 1.58 (1.01-2.48) (*p* for trend 0.063). A similar trend between PRS and low HDL was observed. There was a marginally significant inverse association between rice intake and high TG. However, no association between PRS and plasma triglyceride levels was found. Rice intake as well as PRS was not associated with incident central obesity. In all models, there was no association between PRS and the metabolic syndrome. Using rice intake as a continuous variable in the multivariable analysis did not show any significant association with the risk of the metabolic syndrome (data not shown), nor was there an association between the risk of the metabolic syndrome and PRS. Additional adjustment for vegetable and animal food intake did not change the associations. The results were consistent in both men and women (data not shown).

DISCUSSION

Over the 5-year follow up period of this study the mean weight gain was 0.8 kg. A substantial proportion (14.7%) of the sample developed the metabolic syndrome. Rice intake and PRS were inversely associated with weight gain and the risk of high blood pressure but positively associated with elevation of fasting blood glucose. There was an inverse association between rice intake and PRS with low HDL. No association between rice intake, PRS and the metabolic syndrome was found.

During the five years of follow up, 14.7% of the sample developed the metabolic syndrome. This could be due

Table 4. Multilevel mixed-effects linear regression analysis β coefficients (95% confidence intervals) for groups of rice and percentage of rice in staple foods (PRS) intake predicting 5 year change in weight in 1231 adults participating in the Jiangsu Nutrition Study (JIN) †

	Rice intake groups (g/day)			*p* for trend	PRS	*p*
	0-200 (n=347)	201-400 (n=430)	≥401 (n=454)		every 10% increase	
Model 1, adjusted for age and sex	Reference	-0.82 (-1.46, -0.17)	-2.00 (-2.65, -1.36)	<0.001	-0.27 (-0.35, -0.19)	<0.001
Model 2 ‡	Reference	-0.79 (-1.45, -0.13)	-1.97 (-2.64, -1.31)	<0.001	-0.28 (-0.37, -0.19)	<0.001
Model 3 §	Reference	-0.81 (-1.47, -0.15)	-2.08 (-2.75, -1.41)	<0.001	-0.28 (-0.37, -0.19)	<0.001

†All models were adjusted for baseline weight. Household was treated as a cluster variable.
‡Multivariable model adjusted for variables in model 1 and smoking (yes/no), alcohol drinking (yes/no), active commuting (no, 1-30, and >30 minutes/day), leisure time physical activity (no, 1-30, and >30 minutes/day), education (low, medium, and high), and occupation (manual/non-manual).
§Adjusted for variables in model 2 and energy intake.

Table 5. Odds ratio (95% confidence interval) of metabolic syndrome components according to rice intake, PRS among adults in China

	Rice intake (g/day)			*p*	PRS	*p*
	0-200	201-400	≥401		every 10% increase	
Hyperglycemia (n=1025)	23 (259) †	47 (362)	55 (364)			
Age, gender and baseline glucose adjusted (model 1)	1	1.87 (1.06, 3.31)	2.17 (1.23, 3.81)	0.013	1.20 (1.09, 1.31)	<0.001
Multivariable model (model 2)‡	1	1.96 (1.07, 3.60)	2.50 (1.37, 4.57)	0.005	1.22 (1.11, 1.35)	<0.001
High blood pressure (n=683)	73 (207)	73 (252)	60 (224)			
Age, gender and baseline systolic blood pressure adjusted (model 1)	1	0.62 (0.40, 0.96)	0.52 (0.33, 0.82)	0.002	0.90 (0.85, 0.95)	<0.001
Multivariable model ‡	1	0.68 (0.43, 1.08)	0.58 (0.36, 0.93)	0.009	0.90 (0.85, 0.95)	<0.001
Abnormal HDL (n=760)	84 (200)	121 (253)	150 (307)			
Age, sex, baseline HDL adjusted (model 1)	1	1.44 (0.92, 2.23)	1.65 (1.08, 2.54)	0.031	1.07 (1.01, 1.13)	0.027
Multivariable model ‡	1	1.48 (0.93, 2.35)	1.58 (1.01, 2.48)	0.063	1.07 (1.01, 1.13)	0.033
Abnormal TG (n=945)	63 (297)	48 (310)	56 (335)			
Age, sex, baseline TG adjusted (model 1)	1	0.56 (0.34, 0.91)	0.60 (0.37, 0.97)	0.023	0.97 (0.91, 1.03)	0.268
Multivariable model ‡	1	0.60 (0.36, 1.02)	0.63 (0.38, 1.06)	0.055	0.98 (0.91, 1.05)	0.517
Central obesity (n=873)	42 (226)	56 (324)	42 (323)			
Age, sex, baseline waist circumference adjusted (model 1)	1	0.81 (0.46, 1.45)	0.74 (0.40, 1.37)	0.385	1.02 (0.94, 1.11)	0.659
Multivariable model ‡	1	0.73 (0.41, 1.30)	0.64 (0.34, 1.19)	0.619	1.05 (0.98, 1.12)	0.180
Metabolic syndrome (n=935)	47 (264)	41 (321)	49 (350)			
Age, sex adjusted (model 1)	1	0.60 (0.38, 0.96)	0.90 (0.57, 1.42)	0.506	0.98 (0.93, 1.04)	0.563
Multivariable model ‡	1	0.70 (0.39, 1.26)	0.76 (0.43, 1.36)	0.322	1.02 (0.95, 1.09)	0.660

† values were number of new cases and number of participants
‡Multivariable model adjusted for variables in model 1 and smoking (yes/no), drinking (yes/no), active commuting (no, 1-30, and >30 minutes/day), leisure time physical activity (no, 1-30, and >30 minutes/day), education (low, medium, and high), occupation (manual/non-manual), and energy intake.

to rapid nutrition transition in China. A rapid increase in the prevalence of diabetes has been observed during the same period in China.[30] The results suggest an urgent need to prevent the metabolic syndrome in the population.

The mean daily intake of rice of 321 g was about 40 g higher than the average national consumption,[31] but large variations in rice consumption were found. In the region, more than 99% of the rice consumed is white rice. Rice consumption was inversely associated with wheat flour consumption. Rice and wheat flour represented two different staple foods in China, and therefore the comparison of intake in a geographically small province with a primarily Han population is essentially an ecological study that permits some conclusions to be drawn from these different dietary patterns.

Compared with low rice intake (<200 g/day), weight gain was 2 kg less with a consumption of rice 400 g/day. Every 10% increase in PRS was associated with a 0.28 kg decrease in weight gain. Several mechanisms may explain the association between rice intake and weight change. Firstly, rice is a low-energy food that contributes to the bulk of the traditional diet. Compared with wheat flour, rice absorbs more water when cooked. In addition, different cooking methods are used in preparing these two staples. For instance, steamed rice contains twice the amount of water and half of the energy compared with steamed bread.[29] Thus, the energy density of the rice is lower than the wheat staple diet; high energy dense diets are related to obesity.[32,33] The difference in energy intake across levels of rice intake was relatively small, and therefore is unlikely to be responsible for the lower weight gain of the magnitude seen. The higher rice intake was paradoxically associated with a higher intake of fat and lower intake of fiber which was highest among people in the lowest group of rice intake. Thus, the differences in weight gain between the groups cannot be explained by intake of energy, fat or fiber.

We observed a positive association between rice intake, PRS and the risk of elevation of fasting blood glucose. Each 10% increase of PRS was associated with a 22% increase of the risk of elevation of fasting blood glucose, and may be associated with the fact that rice has a high glycemic index value. The association between rice intake and high intake of fat and low intake of fiber could also explain the link between rice intake and elevation of fasting glucose.

There was an inverse association between rice intake, PRS and hypertension. Rice intake ≥401 g/day was associated with a 42% decrease in the risk of hypertension, as compared with rice intake <200 g/day. A consistent association between PRS and hypertension was found with every 10% increase in PRS associated with a 9% decrease in the risk of hypertension. This association suggested that rice may play a role in the prevention of hypertension. This association cannot be explained by the sodium and fat intake because there was a positive association between rice intake and sodium intake in the sample. However, rice protein has been shown to prevent hypertension in an animal study.[22]

A U shape association between rice intake and some behavior variables (eg smoking, active commuting) was noted among all three groups. This could be due to the age and gender differences across the three groups. These behavior differences could confound the findings of rice intake and health outcomes. However, since age, gender, and behavior variables were included in the multivariate models, the influence might not be substantial.

Because of the high prevalence of the metabolic syndrome and its individual components, to assess the association between rice intake, PRS and the risk of developing individual components of the metabolic syndrome, we can only exclude those with corresponding abnormal component at baseline to ensure sufficient sample size. This led to the different number of participants in the analyses for individual components. Although the sample size is not very large for some analyses (e.g. for the analysis of high blood pressure, n=683), we still found significant associations between rice intake and components of the metabolic syndrome.

To our knowledge, this is the first prospective study looking at the association between rice intake, PRS, weight gain and the metabolic syndrome. It is tempting to speculate that the lower HDL observed in association with the higher rice intake may be accounted for by the high GI of the rice,[20,21] particularly given the relatively higher fasting plasma glucose levels. Our study suggested that rice and wheat intake may affect blood lipids differently. Such difference was seen in other populations. For example, rice intake was inversely and wheat intake was positively related to the total cholesterol level in the Japanese population.[34]

Several limitations exist in the study. Sleep duration,[35] psycho-social stress,[36] and exposure to environmental toxins [37-39] have all been associated with an increased risk of developing the metabolic syndrome. These factors were not measured or analyzed. A further limitation of the study is the high rate loss to follow up due to migration and city construction. There was, however, no significant difference in the mean BMI between those lost to follow up and those retained, thus it is an unlikely source of bias for the association between rice intake and weight change. Strengths of the study include the inclusion of participants using rice and wheat flour as staple foods, and the direct measurement of weight by health workers.

Interpretation and use of our finding should be done with caution. As rice and wheat flour are two main staple foods, an inverse association between PRS and weight gain would suggest a positive association between wheat flour intake and weight gain. Simply recommending increase or decrease of rice consumption in order to prevent disease is not scientifically sound from this single study.

Conclusion

In conclusion, the current study suggests both advantages and disadvantages of rice intake. Substitution of rice for flour favors weight control. Further research is needed to elucidate the effects of rice in the context of overall dietary pattern on human health.

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AUTHOR DISCLOSURES

The authors declare no conflict of interest.

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Original Article

Rice intake, weight change and risk of metabolic syndrome development among Chinese adults: the Jiangsu Nutrition Study (JIN)

Zumin Shi MD, PhD[1,2], Anne W Taylor PhD[2], Gang Hu MD, PhD[3], Tiffany Gill PhD[2], Gary A Wittert MBBch, MD[2]

[1] *Department of Nutrition and Foodborne Disease Prevention, Jiangsu Provincial Centre for Disease Control and Prevention, Nanjing, China*
[2] *Discipline of Medicine, University of Adelaide, Frome Rd, Adelaide, Australia*
[3] *Chronic Disease Epidemiology Laboratory, Pennington Biomedical Research Centre, Louisiana State University System, Baton Rouge, LA, USA*

中国成年人大米摄入及体重变化与代谢综合症风险间的关系研究

目的：分析大米摄入、主食模式(大米占主食的百分比；PRS)及体重变化与代谢综合症风险间的关系。方法：对 1231 名年龄 20 岁及以上的成年人进行了五年跟踪（2002-2007）。食物摄入情况采用食物频率问卷获得。对被调查者进行体重、身高、腰围、血压、空腹血糖和血脂测量。代谢综合症诊断采用国际糖尿病联盟的标准。结果：与每天摄入大米小于 200 克的人群相比，大米摄入量每天大于 401 克的人群，体重增长少 2.08 公斤(95%可信区间：2.75-1.41；*p*<0.001)、高血压风险低 42%（*p*=0.024）。大米摄入和高血糖风险呈线性关系：大米摄入量水平<200、201-400 及≥401 克/天的高血糖风险 OR 值分别为 1、1.96 及 2.50 (95%可信区间: 1.37-4.57；趋势效应 *p*=0.005)。大米摄入与高密度脂蛋白异常发生率呈正相关，但与甘油三酯异常风险无关。PRS 每增加 10%，体重就减少 0.28 公斤、高血糖风险增加 22%、高血压风险降低 9%。大米摄入、PRS 与代谢综合症风险无关。结论：大米摄入、PRS 与体重增长呈负相关，PRS 与高血压风险呈负相关，但与血糖升高呈正相关。未发现大米摄入及 PRS 与代谢综合症相关。

关键词：大米摄入、体重变化、代谢综合症、中国人、队列研究