Original Article

White Rice Consumption is a Risk Factor for Metabolic Syndrome in Tehrani Adults: A Prospective Approach in Tehran Lipid and Glucose Study

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Abstract

Background: Consumption of white rice has been proposed as a dietary risk factor for development of metabolic disorders and type 2 diabetes, especially in populations who consume white rice as a staple food. In this study, we investigated the association between consumption of white rice and the occurrence of metabolic syndrome in Tehrani adults after 3 years of follow-up.

Methods: This longitudinal study was conducted within the framework of the Tehran Lipid and Glucose Study on 1476 adults, aged 19–70 years. Dietary intakes were measured using a validated semi-quantitative food frequency questionnaire at baseline. Biochemical and anthropometric measurements were assessed and documented at baseline (2006–2008) and again 3 years later (2009–2011). Multiple logistic regression models were used to estimate the occurrence of the MetS in each quartile of white rice consumption.

Results: The mean age of participants was 37.8 ± 12.3 years, and mean BMI was 26.0 ± 4.5 Kg/m^2 at baseline. Participants in the highest quartile of white rice consumption were significantly younger, had lower HDL-C levels, and higher systolic and diastolic blood pressures at baseline ($P < 0.01$). Higher consumption of white rice was also accompanied by higher increase in serum triglyceride levels after the 3-year follow-up (9.9 ± 2.3 *vs.* 8.2 ± 2.3%, $P < 0.01$). After adjustment for all potential confounders, the risk of metabolic syndrome in the highest quartile of white rice consumption compared with the lowest, was 1.66 (95% CI: 1.04–2.66). Moreover, participants with central obesity, low physical activity or low-fiber diet had greater risk of metabolic syndrome if white rice constituted ≥25.6% of total energy.

Conclusion: We demonstrated that higher consumption of white rice may be a risk factor for development of metabolic syndrome among Iranian adults.

Key words: abdominal obesity, dyslipidemia, hypertension, insulin resistance, metabolic syndrome

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Introduction

Metabolic syndrome, also named the insulin resistance syndrome, has been identified as a clustering of metabolic disorders including abdominal obesity, impaired glucose homeostasis, dyslipidemia (increased triglycerides and reduced high-density lipoprotein cholesterol) and hypertension, all of which directly promote the development of type 2 diabetes and cardiovascular disease.[1,2] Lifestyle factors, especially physical activity and dietary patterns have been considered as major factors contributing to the incidence of metabolic syndrome among different populations worldwide.[3–6] Effects of total dietary carbohydrate, as well as its sources and quality, on insulin resistance and metabolic syndrome is one of the most controversial issues; however, most studies have concluded that fiber-rich carbohydrate sources such as whole grains, unlike poor-fiber carbohydrate sources such as refined grains, lead to better metabolic outcomes, particularly attenuation of insulin resistance, a main feature of metabolic syndrome.[7–9] Rice is an important grain and is considered as staple food for two-thirds of the world population. Compared to brown rice (hulled rice), white rice is the predominant type of rice consumed.[10] In contrast to brown rice, white rice contains more starch, less fiber, bioactive components, vitamins and minerals, and has higher glycemic index (64 ± 7 *vs.* 55 ± 5).[11,12] Although most investigations suggested that consumption of white rice contributes to development of type 2 diabetes and cardiometabolic risk factors, particularly among populations including Asians who consume rice as a staple food, some studies have reported different results[12–16]. Currently, it seems that there is no consensus on this subject.

In the Iranian dietary patterns, white rice is a main component and provides a major part of daily energy and carbohydrate requirements[17]. To our knowledge, however, the effects of habitual white rice consumption on metabolic outcomes, especially the metabolic syndrome, have been rarely studied in this population. In the current prospective population-based study, we aimed to answer the question whether consumption of white rice could affect the occurrence of metabolic syndrome after 3 years of follow-up in Tehrani adults.

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Material and Methods

Study population

This study was conducted within the framework of the Tehran Lipid and Glucose Study (TLGS). Briefly, TLGS is a community-based ongoing prospective study being conducted to investigate and prevent non-communicable diseases in a representative sample of residents, aged ≥3 years, from district 13 of Tehran, the capital of Iran. The first phase of the TLGS began in March 1999 and data collection, at three-year intervals, is ongoing.[18]

Baseline examination of the current study included 2799 adults (1129 men and 1438 women), aged 19–70 years, with complete data (demographics, anthropometrics, biochemicals and dietary data), who participated in the third phase of TLGS (2006–2008).[19] Participants were excluded from the final analysis if they reported implausible energy intake (below 800 Kcal/d or over 4200 Kcal/d) or were on specific diets (n = 262), had no follow-up information on anthropometrics and biochemical measurements on the second examination in 2009–2011 (n = 629), or were consistent with the definition of metabolic syndrome at baseline (n = 432). Finally, data from 1476 participants was included in the analysis. The mean duration of the follow-up was approximately 3 years.

Informed written consents were obtained from all participants and the study protocol was approved by the ethics research council of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences.

Metabolic syndrome components were defined according to the diagnostic criteria proposed by NCEP ATP III,[20] and the new cutoff points of waist circumference for Iranian adults.[21] Participants were considered to have metabolic syndrome at baseline if possessing least 3 of the metabolic abnormalities: 1) Hyperglycemia: Fasting blood glucose ≥100 mg/dL (5.6 mmol/L) or medical treatment of impaired fasting glucose; 2) Hypertriglyceridemia: Serum triglycerides ≥150 mg/dL (1.69 mmol/L) or medical treatment; 3) Low HDL-C: Serum HDL-cholesterol <40 mg/dL (1.04 mmol/L) for men, and <50 mg/dL (1.29 mmol/L) for women or medical treatment; 4) Hypertension: Blood pressure ≥130/85 mmHg or medical treatment for hypertension and 5) Abdominal obesity: Waist circumference ≥95 cm for both genders. Metabolic syndrome incidence after the 3-year follow-up was determined by the same criteria used at baseline. After 3 years, 249 participants were diagnosed with metabolic syndrome.

Data collection

At baseline, some known or suspected risk factors for metabolic syndrome including age, smoking status, educational level, body mass index, waist circumference and physical activity were assessed. Smoking status was determined through face-to-face interviews; subjects who smoked on a daily basis or occasionally were considered current smokers, while non-smokers included those who had never smoked and those who had quit smoking. Weight was measured to the nearest 100 g using digital scales, while the subjects were minimally clothed without shoes. Height was measured to the nearest 0.5 cm, in a standing position without shoes, using a tape meter. Body mass index was calculated as weight (Kg) divided by height squared (m^2). Physical activity level was assessed based on the frequency and time spent on light, moderate, high and very high intensity activities according to the list of common activities of daily life over the past year. Physical activity levels were expressed as metabolic equivalent hours per week (METs h/wk).

To identify the metabolic syndrome, its components including waist circumference, fasting blood glucose, serum triglycerides, HDL-C, and blood pressure were assessed at baseline and again after 3 years. Waist circumference (WC) was measured to the nearest 0.1 cm (at anatomical landmarks), at the widest portion, over light clothing, using a soft, tape meter, without any pressure to the body. Fasting blood samples were taken after 12–14 hours from all study participants at baseline and after a 3-year follow-up. Fasting plasma glucose (FPG) was measured by the enzymatic colorimetric method using glucose oxidase. Triglyceride (TG) level was measured by enzymatic colorimetric analysis with glycerol phosphate oxidase. High-density lipoprotein cholesterol (HDL-C) was measured after precipitation of the apolipoprotein-B-containing lipoproteins with phosphotungstic acid. Analyses were performed using Pars Azmoon kits (Pars Azmoon Inc., Tehran, Iran) and a Selectra 2 auto-analyzer (Vital Scientific, Spankeren, the Netherlands). Inter- and intra-assay coefficients of variation of all assays were both <5%. For blood pressure (BP) measurements, after a 15-minute rest in the sitting position, two measurements of BP were taken on the right arm, using a standardized mercury sphygmomanometer; the mean of the two measurements was considered as the participant's BP.

On first examination, a 168-item food frequency questionnaire (FFQ) was used to assess typical food intake over the previous year. The validity of the food frequency questionnaire was previously evaluated by comparing food groups and nutrient values determined from the questionnaire with values estimated from the average of twelve 24-h dietary recall surveys.[22] Trained dietitians, with at least 5 years of experience in the TLGS survey, asked participants to designate their intake frequency for each food item consumed during the past year on a daily, weekly, or monthly basis. Portion sizes of consumed foods reported in household measures were then converted to grams.

To analyze foods and beverages for their energy and nutrient content, we used the US Department of Agriculture FCT because the Iranian Food Composition Table is incomplete, and has limited data on nutrient content of raw foods and beverages. Dietary intakes of participants including dietary energy and energy density, macronutrients, micronutrients, and food groups, were determined.

Statistical methods

Participants were classified into quartiles of daily consumption of white rice at baseline. Confounding variables considered were sex, age (years, continuous), BMI (Kg/m^2, continuous), total energy intake (Kcal/d), dietary intake of carbohydrate (g/d), protein (g/d), total fiber (g/d). The association between confounding factors and daily consumption of white rice was assessed by chi-square test for categorical variables and linear regression analysis for continuous variables.

Participant characteristics, baseline MetS components and 3-year changes, and the prevalence of MetS on the follow-up examination were compared across quartile categories of white rice consumption using chi-square test for categorical variables or general linear models with adjustment of sex and age for continuous variables.

Mean dietary intakes of participants were compared across quartile categories of white rice consumption using the general linear model, adjusted for sex, age (years, continuous), and energy intakes (Kcal/d). To estimate the odds (95% CI) of MetS on the

second examination for quartile categories of white rice consumption, multivariable logistic regression models were used, with the lowest category used as reference. To assess the overall trends of the odds ratios of the metabolic syndrome across quartile categories of white rice consumption, median intake of white rice in each quartile was used as a continuous variable in the logistic regression models. We also conducted additional analyses to estimate the odds of the metabolic syndrome in each quartile category of white rice consumption, stratified by categories of waist circumference (<95 and ≥95 cm), body mass index (<25 and ≥25 Kg/m^2), dietary fat (<30% and ≥30 % of energy intake), dietary fiber (<14 and ≥14 g/1000 Kcal of energy intake), physical activity levels (<median and ≥median). These analyses were adjusted for all the above mentioned confounders.

All statistical analysis were conducted using SPSS (Version 16.0; Chicago, IL), and *P* values < 0.05 were considered significant.

Results

The mean age of participants was 37.8 ± 12.3 years, and mean BMI was 26.0 ± 4.5 Kg/m^2 at baseline. Thirty nine percent of the participants were men. The mean weight gain was 1.87 ± 5.14 Kg (2.20 ± 5.3 Kg in men and 1.65 ± 4.93 Kg in women) during the 3-year period; there was no significant difference in mean weight gain across quartiles of white rice consumption. Mean daily intake of white rice was 249 ± 173 g/d (293 ± 188 and 220 ± 156 g/d, in men and women, respectively). Mean daily energy intake of white rice from total energy intake also was 14.3% ± 8.56% (16.1% ± 8.8% and 13.1% ± 8.2% in men and women, respectively).

Compared with participants in the lowest quartile, those in the highest quartile of white rice consumption were significantly younger (35.7 *vs.* 39.9 years, $P < 0.01$). There was no significant difference between baseline characteristics of participants, baseline and 3-year changes of metabolic syndrome components across categories of white rice consumption (Table 1). The mean dietary intake of participants across quartile categories of fast food consumption are shown in Table 2. Men and women who consumed higher white rice had lower energy intake and higher dietary energy density ($P < 0.05$). In addition, higher consumption of white rice was associated with higher intake of carbohydrates, and lower intake of proteins, total fats, saturated fats and cholesterol ($P < 0.05$). There was a significant decreasing trend in dietary intake of whole grains, vegetables (both starchy and non-starchy), fruits, total meat and dairy products with increasing consumption of white rice ($P < 0.05$). Dietary intakes of potassium, calcium, vitamins C and E, and riboflavin in participants with higher consumption of white rice were significantly lower while dietary intake of thiamine was higher in these participants ($P < 0.05$). The odds and 95% CI for occurrence of the metabolic syndrome in each quartile category of white rice consumption after the 3-year follow-up are presented in Table 3.

In the age- and sex-adjusted model, a non-significant inverse association was observed between white rice consumption and the risk of the metabolic syndrome. In the second model, after additional adjustment for body mass index, we observed a significant association between white rice consumption and the metabolic syndrome (OR: 1.54, 95% CI: 1.01–2.37). To modify potential ef-

Table 1. Characteristics of participants by categories of white rice consumption: Tehran Lipid and Glucose Study

	(*n* = 1476)			
	Q1 (*n* = 369)	**Q2 (*n* = 369)**	**Q3 (*n* = 369)**	**Q4 (*n* = 369)**
Rice consumption (g/d)				
Range(g/d/1000 Kcal)	<68	68–102	103–142	>142
Mean	93 ± 59	209 ± 58	262 ± 60	432 ± 224
Age at baseline (years)	39.9 ± 12.3	38.2 ± 12.0	37.5 ± 12.6	35.7 ± 12.2 **
Men (%)	27.4	39.7	39.8	50.4
Physical activity (Met-h/week)*	33.5 ± 2.4	36.6 ± 2.4	32.7 ± 2.4	38.1 ± 2.4
Current smoker (%)	9.5	9.8	9.1	11.1
Weight				
At baseline (Kg)*	71.0 ± 0.64	69.3 ± 0.64	70.4 ± 0.64	68.7 ± 0.64
3-year changes (%)*	2.8 ± 0.4	2.9 ± 0.4	2.9 ± 0.4	3.3 ± 0.4
Waist circumference				
At baseline (cm)*	85.5 ± 0.56	86.5 ± 0.55	85.9 ± 0.55	86.0 ± 0.56
3-year changes (%)*	5.9 ± 0.44	6.2 ± 0.44	7.0 ± 0.44	7.2 ± 0.44
Serum triglycerides				
At baseline (mg/dL)*	114 ± 3.1	112 ± 3.1	118 ± 3.1	120 ± 3.1
3-year changes (%)*	8.2 ± 2.3	7.8 ± 2.3	7.1 ± 2.3	9.9 ± 2.3 **
Serum HDL-C				
At baseline (mg/dL)*	45.2 ± 0.5	43.9 ± 0.5	43.9 ± 0.5	42.8 ± 0.5 **
3-year changes (%)*	14.6 ± 1.1	13.8 ± 1.1	13.1 ± 1.1	11.2 ± 1.1
Fasting serum glucose				
At baseline (mg/dL)*	84.9 ± 0.57	85.9 ± 0.56	85.9 ± 0.56	86.8 ± 0.57
3-year changes (%)*	6.8 ± 0.5	6.3 ± 0.5	6.7 ± 0.5	7.4 ± 0.5
Systolic blood pressure				
At baseline (mmHg)*	106 ± 0.7	108 ± 0.7	108 ± 0.7	110 ± 0.7 **
3-year changes (%)*	3.9 ± 1.4	6.6 ± 1.4	4.5 ± 1.4	4.1 ± 1.4
Diastolic blood pressure				
At baseline (mmHg)*	70 ± 0.5	71 ± 0.5	72 ± 0.5	73 ± 0.5 **
3-year changes (%)*	5.2 ± 1.1	6.0 ± 1.1	7.5 ± 1.1	8.3 ± 1.1
Metabolic syndrome (%)	17.1	16.8	16.9	17.9

Data are mean ± SD unless stated otherwise. * Adjusted for age and sex. ** Significant differences across quartiles of white rice consumption (Chi square test, analysis of variance, or linear regression models with adjustment for sex and age was used).

Table 2. Dietary intakes of participants by categories of white rice consumption: Tehran Lipid and Glucose Study

	(n = 1476)			
	Q1 (n = 369)	Q2 (n = 369)	Q3 (n = 369)	Q4 (n = 369)
White rice consumption				
g/d	93 ± 59	209 ± 58	262 ± 60	432 ± 224
Kcal/d	121 ± 76	271 ± 76	342 ± 78	561 ± 292
Kcal/total energy intake	5.1 ± 2.6	10.9 ± 1.3	15.5 ± 1.4	25.6 ± 7.5
Energy and macronutrients				
Energy intake (Kcal/d)	2342 ± 32	2492 ± 32	2204 ± 32	2106 ± 32 *
Energy density(Kcal/100 g of foods)	96 ± 1.2	96 ± 1.2	97 ± 1.2	100 ± 1.2 *
Carbohydrate (g/d)	317 ± 2.2	320 ± 2.2	330 ± 2.2	344 ± 2.2 *
Fat (g/d)	85 ± 0.9	84 ± 0.9	79 ± 0.9	72 ± 0.9
Protein (g/d)	81 ± 0.7	78 ± 0.7	76 ± 0.7	73 ± 0.7 *
Cholesterol (mg/d)	244 ± 5.8	235 ± 5.8	226 ± 5.8	196 ± 5.8 *
Saturated fatty acid (% of total energy)	11.2 ± 0.3	10.9 ± 0.3	10.5 ± 0.3	10.1 ± 0.3 *
Total fiber (g/d)	41.1 ± 0.8	38.4 ± 0.8	37.4 ± 0.8	32.5 ± 0.8 *
Food groups				
Whole grains (g/d)	120 ± 5.2	87 ± 5.2	86 ± 5.2	72 ± 5.2 *
Fruits (g/d)	461 ± 14.4	428 ± 14.4	384 ± 14.4	315 ± 14.4 *
Starchy vegetables (g/d)	31.0 ± 1.3	29.1 ± 1.3	27.5 ± 1.3	24.7 ± 1.3 *
Non-starchy vegetables (g/d)	307 ± 9.0	259 ± 9.0	259 ± 9.0	231 ± 9.0 *
Legumes (g/d)	17.6 ± 1.1	14.9 ± 1.1	15.4 ± 1.1	14.4 ± 1.1
Dairy (g/d)	504 ± 14.5	498 ± 14.5	478 ± 14.5	397 ± 14.5 *
Nuts (g/d)	6.3 ± 0.5	6.7 ± 0.5	7.6 ± 0.5	7.1 ± 0.5
Total meat (g/d)	72 ± 2.2	65 ± 2.2	63 ± 2.2	61 ± 2.2 *
Micronutrients				
Sodium (g/d)	4.7 ± 0.2	4.7 ± 0.2	4.4 ± 0.2	4.2 ± 0.2
Potassium (g/d)	4.1 ± 0.05	3.8 ± 0.05	3.7 ± 0.05	3.3 ± 0.05 *
Calcium (mg/d)	1306 ± 19.2	1287 ± 19.2	1248 ± 19.2	1089 ± 19.2 *
Vitamin C	164 ± 4.1	152 ± 4.1	143 ± 4.1	121 ± 4.1 *
Vitamin E	12.6 ± 0.2	12.4 ± 0.2	11.5 ± 0.2	10.7 ± 0.2 *
Thiamin	1.8 ± 0.02	1.8 ± 0.02	1.9 ± 0.02	2.1 ± 0.02 *
Riboflavin	2.2 ± 0.03	2.1 ± 0.03	1.9 ± 0.03	1.7 ± 0.03 *
Niacin	22 ± 0.5	21.5 ± 0.5	21.8 ± 0.5	23 ± 0.5

Data are mean ± SEM (adjusted for age, sex, or energy intake)
* P <0.05; linear regression models were used to compare dietary intakes of participants across quartiles of white rice consumption.

Table 3. Odds and 95% confidence interval for occurrence of the metabolic syndrome after 3-year follow-up in each quartile categories of white rice consumption: Tehran Lipid and Glucose Study

	(*n* = 1476)				
	Q1 (*n* = 369)	Q2 (*n* = 369)	Q3 (*n* = 369)	Q4 (*n* = 369)	*P* for trend*
Model 1 *	1	0.96 (0.64–1.44)	1.06 (0.71–1.57)	1.22 (0.81–1.82)	0.51
Model 2 ***	1	1.13 (0.73–1.74)	1.82)–0.78)1.19	1.54 (1.01–2.37)	0.23
Model 3 ¶	1	1.11 (0.72–1.72)	1.23 (0.79–1.89)	1.66 (1.04–2.66)	0.18

*To assess the overall trends of odds ratios across quartile categories of white rice consumption, the median for each quartile was used as a continuous variable in logistic regression models. **Adjusted for age at baseline (years) and sex. ***Additional adjustment for body mass index at baseline (Kg/m^2). ¶Additional adjustment for energy intake (Kcal/d), carbohydrate (g/d), protein (g/d), fiber (g/d).

Table 4. Stratified analyses of white rice consumption by anthropometric, dietary factors and physical activity categories on the occurrence of the metabolic syndrome: Tehran Lipid and Glucose Study

	(*n* = 1476)									
	wais circumference (cm)		Body mass index (Kg/m^2)		Dietary fat (% of energy)		Dietary fiber (g/1000 Kcal)		Physical activity (MET/h-w)	
	<95	≥95	<25	≥25	<30	≥30	<14	≥14	<median	>median
Q1	1	1	1	1	1	1	1	1	1	1
Q2	0.59 (0.34–1.04)	1.72 (0.88–3.36)	0.87 (0.33–2.28)	1.02 (0.64–1.62)	1.28 (0.65–2.54)	0.82 (0.49–1.38)	1.00 (0.43–2.33)	1.2 (0.72–2.03)	1.68 (0.84–3.37)	0.82 (0.46–1.44)
Q3	0.92 (0.54–1.55)	1.56 (0.78–3.12)	0.78 (0.27–2.22)	1.17 (0.70–1.71)	1.18 (0.59–2.33)	1.10 (0.65–1.87)	1.83 (0.83–4.05)	0.99 (0.58–1.69)	1.53 (0.75–3.11)	1.02 (0.58–1.79)
Q4	1.02 (0.58–1.78)	2.35 (1.08–5.10)	1.40 (0.47–4.15)	1.33 (0.80–2.20)	1.56 (0.78–3.10)	1.30 (0.71–2.40)	2.38 (1.05–5.41)	1.14 (0.60–2.15)	2.73 (1.31–5.71)	1.12 (0.58–2.11)

Data are odd ratio (95 % confidence interval) multivariable logistic regression models were used with adjustment for sex, age (years, continuous), body mass index at baseline (Kg/m^2), total energy intake (Kcal/d), carbohydrate (g/d), protein (g/d), fiber (g/d).

fects of dietary factors, we made additional adjustments for total daily energy intake, dietary intake of carbohydrate, protein, and fiber in the last model; the results showed an elevated risk of the metabolic syndrome in the highest quartile of white rice consumption (OR:1.66, 95% CI: 1.04–2.66). Further analyses stratified by categories of waist circumference and body mass index showed that higher consumption of white rice was more strongly related to the risk of the metabolic syndrome in participants with abdominal obesity (OR: 2.35, 95% CI: 1.08–5.10 *vs.* OR:1.02, 95% CI: 0.58–1.78) (Table 4). Additional analyses stratified by categories of dietary fat and dietary fiber also revealed that the association of white rice and the risk of the metabolic syndrome was more pronounced in participants on low-fiber diets (OR: 2.38, 95% CI: 1.05 – 5.41 *vs.* OR: 1.14, 95% CI: 0.60 – 2.15). Compared to highly active persons, participants with lower physical activity levels (<median) had greater risk of the metabolic syndrome in relation to higher consumption of white rice (OR: 2.73, 95% CI: 1.31–5.71 *vs.* OR: 1.12, 95% CI: 0.58–2.11) (Table 4).

Discussion

In this prospective study, we observed a positive association between daily consumption of white rice and the occurrence of the metabolic syndrome after a 3-year follow-up in Tehrani adults. This association was strengthened after considering potential confounders of the metabolic syndrome and dietary factors. Mean daily consumption of white rice > 430 g/d (more than 25% of total energy intake/d) increased the risk of the metabolic syndrome in men and women approximately up to 66%. In our study, stratified analysis also showed that adverse effects of white rice consumption on the occurrence of the metabolic syndrome may be strengthened in participants who had abdominal obesity, were physically inactive or had a low-fiber diet.

In our study, we observed that higher consumption of white rice was related to lower dietary intake of potassium, calcium, vitamin C, vitamin E, and riboflavin which could be considered in line with lower consumption of dairy products, fruits and vegetables. Moreover, dietary intake of thiamine was increased across the quartile categories of white rice consumption; the explanation for this observation is that although white rice contains less thiamine compared to whole grains and nuts, increased consumption of white rice is accompanied by higher thiamine intake.

In this study, higher consumption of white rice was also associated with lower energy intake (Kcal) but higher energy density (Kcal/100g of foods); since dietary fiber is a main determinant of dietary energy density, significantly lower intake of dietary fiber in the highest quartile category of white rice could explain this observation. Studies showed that higher energy density is associated with higher risk of the metabolic syndrome and its components.[23,24]

Most studies conducted among Asian populations indicate that consumption of white rice is a dietary risk factor for development of abdominal obesity, type 2 diabetes, insulin resistance and the metabolic syndrome,[15,16] although contradictory results have also been reported.[14] A recent meta-analysis reported that the average intake levels of white rice in Asian populations were 3-4 servings/day, while they were 1–2 servings/week among Western populations. Comparing the highest to the lowest levels of white rice consumption, the relative risk of type 2 diabetes was 1.55 (95% CI: 1.20–2.01) in Asian populations, whereas it was 1.11 (1.08 to 1.14) in Western populations.[25] In a prospective cohort study, higher consumption of white rice, defined as ≥5 servings/week compared to <1 serving/month, was related to increased risk of type 2 diabetes (RR: 1.17, 95% CI: 1.02–1.36); in contrast, higher consumption of brown rice, defined as ≥2 servings/week compared to <1 serving/month decreased the risk of type 2 diabetes.[26] The same results were obtained in a follow-up of middle-age Chinese women; multivariable-adjusted relative risk of type 2 diabetes was 1.78 (95% CI: 1.48–2.15) for women who consumed rice > 300 g/d; this relative risk increased in women who had greater waist to hip ratio (≥0.85), were overweight (BMI ≥ 25), had low physical activity levels, or had higher insulin resistance.[15] In contrast with our results and other studies, a 5-year follow-up of Chinese adults in the Jiangsu Nutrition Study showed that consumption of white rice >401 g/day was associated with less weight gain (-2.08 kg, 95% CI: -2.75, -1.41), and 42% lower risk of hypertension compared to rice consumption of <200 g/day.[14]

In our study, we observed that participants with overweight and abdominal obesity were also at greater risk of metabolic disorders if they consumed more white rice. Another study also reported that overweight and obese subjects were more susceptible to metabolic disorders, type 2 diabetes and cardiovascular disease if they had a high carbohydrate diet, high glycemic index diet or higher consumption of white rice.[15,27]

Considering the null association which we observed between white rice consumption and the metabolic syndrome in high-fiber diet (≥14g/1000 Kcal), compared to the more pronounced association between consumption of white rice and the metabolic syndrome in low-fiber diets (<14g/1000 Kcal), it can be concluded that higher intake of dietary fiber and fiber-rich foods could attenuate the adverse metabolic outcomes of white rice consumption. Recent findings from the Korean Genome and Epidemiology Study revealed that rice-eating patterns, including consumption of white rice either *per se* or combined with beans or grains, could have different effects on the risk of the metabolic syndrome; consumption of rice with beans and multi-grains, compared to white rice, was significantly related to lower risk of central obesity and impaired fasting glucose.[28] Other studies have also emphasized that combination of white rice with whole grains, including barely or brown rice, was accompanied by better postprandial outcomes including reduced postprandial levels of glucose, insulin and ghrelin, as well as better weight control, and improvement of lipid profiles and antioxidant enzymes activity.[29,30] These findings could be the basis for dietary recommendations among populations eating white rice as a staple food.

Although most related studies provide evidence that high consumption of white rice is associated with undesirable metabolic outcomes, potential mechanisms have not been explained clearly. White rice has a high glycemic index and is a predominant contributor to dietary glycemic load, especially among populations which consume white rice as a staple food; studies show that high glycemic load and glycemic index diet independently increase the risk of developing type 2 diabetes and related disorders.[31] Regular consumption of high GI foods could induce chronic hyperglycemia and increased workload of pancreatic β cells, as well as insulin resistance, through increased free fatty acid levels and counter regulatory hormones. These metabolic changes lead to decreased concentration of HDL-cholesterol, increased oxidative stress and endothelial dysfunction.[32,33] As compared to whole grains which are minimally processed, white rice has lower amounts of essential nutrients and bioactive compounds including fiber, lignans,

phytoesterogens, phenolic compounds and acid phytic, vitamins and minerals. It is obvious then that consumption of white rice as the basic dietary grain leads to a diet low in fiber, nutrients and phytochemicals which have health promoting effects and prevent against metabolic disorders.[34]

Some limitations of the current study should be considered; the usual dietary intakes of participants were assessed only at baseline, while several evaluations of dietary intakes could have increased the validity of the results. Using the USDA FCT, rather than a comprehensive Iranian FCT is another limitation.

In conclusion, we demonstrated that higher consumption of white rice may increase the incidence of the metabolic syndrome, especially in subjects with central obesity, low physical activity or low-fiber diet, independently from known and suspected confounding variables. However, the weak association warrants further studies to clarify this association.

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