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White rice intake varies in its association with metabolic markers of diabetes and dyslipidemia across region among Chinese Adults

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Abstract

Background/Aims—There are inconsistent associations between white rice consumption with diabetes and dyslipidemia, perhaps due to the nature of samples studied and quality of diet data.

Methods—Using regionally diverse data from adults enrolled in the China Health and Nutrition Survey (n=7,878) with diet data from three repeated 24-hour recalls and fasting blood to derive diabetes and dyslipidemia, we examined the odds of diabetes and dyslipidemia in participants across region-specific tertiles of percent energy from white rice consumption.

Results—The prevalence of undiagnosed diabetes, high triglycerides, high low-density lipoprotein (LDL), low high-density lipoprotein (HDL), and atherogenic dyslipidemia (AD) were 4.7%, 31.8%, 31.3%, 25.9%, and 14.6%, respectively. We found an inverse association between highest (versus lowest) tertile of rice intake and diabetes in Central China [Odds Ratio (OR): 0.59, 95% CI: 0.36–0.99]. Highest rice consumption was also associated with high triglycerides (OR: 1.46, 95%CI: 1.09–1.95), low HDL (OR: 1.38, 95%CI: 1.03–1.85) and AD (OR: 1.63, 95%CI: 1.15–2.31) in the North, and low LDL (OR: 0.54, 95%CI: 0.42–0.69) in the Central.

Conclusions—The association between white rice consumption with diabetes and dyslipidemia markers varied across regions of China, suggesting a role of other dietary and health-related exposures, beyond rice.

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Disclosure Statement

The authors have no conflicts of interest to disclose.

All authors contributed to conception, design, and interpretation of data, F.D. contributed to data analysis, B.M.P. and P.G.L. contributed to the acquisition of data, F.D. and P.G.L. drafted the manuscript and A.G.H., A.H.H., and B.M.P. contributed to critical revision of the manuscript. F.D. and P.G.L. had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. All authors have read and approved the final manuscript.

Keywords

White rice intake; Diabetes; Dyslipidemia; Chinese adults

Introduction

The prevalence of type 2 diabetes mellitus (T2DM) in China has increased dramatically from 0.8% in 1979 to 8% in 2012[1], along with a surge in dyslipidemia[2]. T2DM and dyslipidemia often coexist[3]. White rice is a major staple food in Asia, but with regional variation [ranging from high (Southern China) to low (Central China) consumption]. The literature on rice consumption and T2DM is mixed[4–11], ranging from positive[8, 10, 11], null[4, 5, 9] to negative[7], as is the association with markers of dyslipidemia [positive or no association with high triglycerides and/or low high-density lipoprotein (HDL)[5, 10, 12–15]]. These inconsistent findings may relate to the nature of samples studied, quality of diet data, or different biological effects rather than heterogeneity in results across studies.

To address this inconsistency, we used regionally diverse data from adults enrolled in the China Health and Nutrition Survey (CHNS) to examine associations between white rice intake with markers of diabetes and dyslipidemia [high triglycerides, high LDL, low HDL, and atherogenic dyslipidemia (AD, high triglycerides *and* low HDL, an important risk factor for cardiovascular disease)], with attention to regional variation in rice consumption.

Methods

CHNS

In seven survey rounds, the CHNS collected health data in 228 communities in nine diverse provinces throughout China(North: Heilongjiang, Liaoning; Central: Shandong, Henan, Jiangsu; South: Hunan, Hubei, Guangxi, Guizhou) from 1991–2009. Questionnaires were used to collect demographic, socioeconomic, anthropometric, behavioral and health information. The 2009 survey collected fasting blood for the first time. Using a multistage, random cluster design, a stratified probability sample was used to select counties and cities stratified by income using State Statistical Office definitions [16] and then communities and households were selected from these strata. The CHNS cohort initially mirrored national age-gender-education profiles[17–19] and the provinces in the CHNS sample constituted 44% of China's population in 2009 (according to 2009 census).

Survey procedures have been described elsewhere[20]. The study was approved by the Institutional Review Board at the University of North Carolina at Chapel Hill, the China-Japan Friendship Hospital, Ministry of Health and the Institute of Nutrition and Food Safety, China Centers for Disease Control and subjects gave informed consent for participation.

Analysis sample

We restricted analyses to adults (≥ 18 and <98 years) at the 2009 exam (*n*=8616).We excluded individuals who were pregnant(*n*=61, 0.7%), or missing diet (*n*=115, 1.3%) or blood biomarker(*n*=19, 0.2%)data, or were not fasting before blood withdrawal (*n*=402, 4.7%). We further excluded individuals with previous diabetes diagnosis to reduce the possibility of reverse causality(*n*=232, 2.7%), resulting in final analytic samples of 7628(diabetes) and 7878 (dyslipidemia).Excluded subjects were younger, slightly better educated, and more likely to be in the Southern region than the analytic sample. There were no statistically significant differences in sex, body mass index (BMI, weight/height^2), income, and urbanization levels.

Ascertainment of diabetes and dyslipidemia

Blood samples were collected by venipuncture after overnight fasting (12mL). Whole blood was immediately centrifuged and serum immediately used to measure glucose using a glucose oxidase phenol 4-aminoantipyrine peroxidase kit (GOD-PAP; Randox, Crumlin, UK). Diabetes was classified using fasting blood glucose (FBG) ≥7.0 mmol/L (*n*=359) in our main analysis[21]. In sensitivity analysis, we defined diabetes using hemoglobin A1c (HbA1c) ≥ 6.5% (*n*=447)[22]. Total triglycerides, HDL, and LDL were measured using the glycerol-phosphate oxidase method, and the polyethylene glycol (PEG)-modified enzyme method, by determiner regents (Kyowa Medex Ltd, Tokyo, Japan), using a Hitachi 7600 automated analyzer (Hitachi Inc., Tokyo, Japan). Dyslipidemia was defined following the International Diabetes Federation criteria (high triglycerides: ≥150 mg/dL, *n*=2,488; low HDL: men <40 mg/dL, women <50 mg/dL, *n*=2,450; high LDL: >130 mg/dL, *n*=2,041) or use of lipid lowering medication (*n*=31)[23]. AD was defined as having high triglycerides *and* low HDL (*n*=1,148)[24].

Dietary assessment

Dietary intake was assessed using three consecutive 24-hour recalls at the individual level and a food inventory at the household level collected during the same 3-day period, randomly starting from Monday to Sunday. All foods available in the household were measured on a daily basis for the food inventory. For the 24-hour recalls, trained interviewers recorded types and amounts of foods consumed. Daily average consumption (g/day) of white rice and other foods were estimated. Proportion of energy from rice was then calculated by dividing daily average energy intake from rice by daily average total energy intake. The nutrient contents were based on a Chinese food composition table[25]. Raw rice was reported but mostly consumed as steamed rice. Total energy intake was validated with the doubly labeled water method in the Human Nutrition Research Center, Tufts University (correlation coefficients between the two methods were 0.56 for men and 0.60 for women[26]).

Statistical analyses

White rice intake (% total energy) was categorized into region-specific tertiles (North, Central, South). We tested differences in descriptive characteristics by categories of rice consumption and by region using ANOVA (continuous variables) and chi-square tests (categorical variables). We tested correlations between rice consumption and other food groups (percent energy from food groups) using Pearson's correlation, and generated two-factor analysis-derived dietary patterns (Supplemental Methods) to capture dietary confounders as dietary pattern scores[27]. We used multivariable logistic regression models to estimate odds ratios (OR), adjusting for household clustering using the robust cluster command. Given a statistically significant (p<0.01) interaction for rice by region and because of substantial regional variation in diet, cooking methods, and lifestyle factors across China, we ran models by region.

We present results for multivariable fully-adjusted models including age (continuous with linear and quadratic terms), gender, education (below/equal to/above high school), urbanicity (low/medium/high), hypertension diagnosis (yes/no), total physical activity (METs/week, quartiles), total energy intake (kcal/day, quartiles), dietary pattern scores (quartiles), and BMI (kg/m^2, quartiles). Additionally, diabetes models included fiber (g/day, quartiles) and magnesium (mg/day, quartiles) intakes; dyslipidemia models included fat intake (% energy from fat, quartiles). We tested smoking (yes/no), alcohol intake (g/day, quartiles), and income (low/medium/high) but they did not change the estimates, thus were not retained; neither were fat intake and lipid levels in the diabetes models. We also tested for interaction between rice intake with age and gender in all models, and with dyslipidemia medication use in dyslipidemia models. Tests for linear trend across increasing rice intake categories were conducted by modeling the categories as a continuous variable using the median value for each category. Since white rice and wheat products are the two main types of staple foods consumed in China, we also evaluated the association of "substituting" 10% of total energy from wheat products as staple food (wheat bun and noodles) for 10% of total energy from rice with diabetes and dyslipidemia. We did the analysis by simultaneously including rice and wheat products intake as continuous variables in the same multivariable model. The difference in their coefficients and their covariance were used to estimate the OR and 95% confidence intervals for the substitution, respectively[28]. All analyses were performed using Stata 13 (StataCorp), with two-sided p<0.05 considered statistically significant.

Results

Median percent energy from white rice was the highest in the South (43%) and lowest in the Central (13.5%) region. Overall, a greater proportion of participants at the highest (versus lowest) rice consumption tertile were leaner, of lower education and income, and living in less urbanized areas (Table 1). Physical activity was higher, whereas fiber, fat, and magnesium intakes were lower at the highest rice consumption tertile. Most descriptive characteristics varied significantly (p<0.001) across regions.

Correlations between consumption of rice and other food groups are shown in Supplement Table 1. Rice consumption was negatively correlated with wheat products consumption. To control for dietary confounding, we used region-specific factor scores to examine other dietary factors (beyond rice) with potential influence on diabetes and dyslipidemia markers (factor loadings in Table 2). Two Northern patterns were characterized by high consumption of low-sugar wheat and milk (western pattern), and high cakes & pastries and soymilk (traditional pattern), respectively. In the Central region, we identified a low-wheat pattern (low wheat as staple food and high fish & seafood) and a western pattern (high low-sugar wheat, red meat, eggs and milk). Two Southern patterns were featured by high intakes of cakes & pastries and milk (western pattern) and high wheat as staple food (high-wheat pattern), respectively. White rice consumption had a strong positive correlation with the low-wheat pattern in the Central region (r=0.64, p<0.05), and moderate negative correlations with the traditional pattern in the North, western pattern in the Central and both western and high-wheat patterns in the Southern region (r=−0.24, −0.22, −0.27, and −0.29, respectively, p<0.05).

Diabetes

In 2009, 359 out of 7628 participants had undiagnosed diabetes, with variation across region (North: 5.2%; Central: 5.7%; South: 3.7%, Table 3). Fully-adjusted multivariable models suggest that the highest (versus the lowest) category of rice intake was associated with lower prevalence of diabetes in the Central region (OR: 0.59, 95% CI: 0.36–0.99). In Supplement Table 2, we present results for crude age- and gender-adjusted models and multivariable models without BMI adjustment. We did not detect interaction between rice intake with age or gender.

Dyslipidemia

The prevalence of high triglycerides, high LDL, low HDL, and AD varied across region (Table 4). Comparing the highest rice consumption category to the reference, there were significantly higher odds of high triglycerides (OR: 1.46, 95%CI: 1.09–1.95), low HDL (OR: 1.38, 95%CI: 1.03–1.85) and AD (OR: 1.63, 95% CI: 1.15–2.31) in the Northern, and lower odds of high LDL (OR: 0.54, 95%CI: 0.42–0.69) in the Central region. In Supplement Table 3, we present results for crude age- and gender-adjusted models and multivariable models without BMI adjustment. We did not detect interaction between rice intake with age, gender, or dyslipidemia medication.

Sensitivity analyses

Using HbA1c to define diabetes did not considerably change the results compared to using FBG (Supplement Table 4). Substitution analysis showed that replacement of 10% energy from wheat products with 10% energy from rice was associated with 12% lower odds of diabetes (95%CI: 0.3%–22%) and 12% lower odds of high LDL ((95%CI: 7%–18%) in the Central region (Supplement Figure 1); 16% higher odds of high triglycerides (95%CI: 5%–27%), 11% higher odds of low HDL (95%CI: 0.2%–23%), and 13% higher odds of AD (95%CI: 1%–26%) in the North.

Discussion

In this population-based, cross-sectional study of Chinese adults, we capitalized on well-measured diet intake data from three 24-hour recalls to examine how white rice consumption was associated with diabetes and dyslipidemia, taking other dietary factors into account. Higher rice consumption was associated with lower prevalence of diabetes and high LDL in the Central region, and higher prevalence of high triglycerides, low HDL, and AD in the North. Substituting the same amount of energy from wheat products with rice showed consistent associations. To our knowledge, ours is the first study to examine rice consumption, diabetes, and dyslipidemia associations in three geographic regions of China that vary in consumption of rice, accounting for other dietary factors.

White rice intake and diabetes

White rice is a staple food in many Asian countries[8]. The association between rice intake and diabetes has been inconsistent in Asian countries[8–11, 14]. Studies in China, Japan, and Singapore found white rice consumption positively associated with FBG or T2DM[8, 10, 11, 14], whereas no association was observed in a Hong Kong population[9]. Particularly, a prospective study conducted in Shanghai China reported a T2DM relative risk of 1.78 (95%CI: 1.48–2.15) comparing middle-aged women who consumed ≥300g/day (versus <200g/day) white rice[8]. However, the southern city of Shanghai has generally high rice consumption with less variability relative to the other regions. Moreover, Villegas et al[8] did not control for other dietary components, which could be important confounders of the rice and diabetes association. Furthermore, Villegas et al. was in a less varied geographic area than our study and they relied on self-reported diabetes cases, which likely underestimates true prevalence, given our observed 61% undiagnosed diabetes. Our use of FBG measures and detailed diet behavior data to control for important dietary confounders improves upon the current literature. While another study in a single province (Jiangsu China) observed a significantly positive association between white rice intake and hyperglycemia risk[14], we found results in the opposite direction, although we have Jiangsu province in our CHNS Central region. The inconsistency could be partially due to their high loss to follow-up rate (above 40%) and the potential confounding effect of other diet components, which were not addressed in their study[14]. Additionally, positive associations were observed only among women in Japan and Shanghai China[8, 11]. In our study, we tested effect measure modification by gender but detected none.

White rice consumption is considerably lower in Western than Asian countries[29]. Studies that found mixed associations have largely been based in Western countries. No association between diabetes and white rice or refined grains was observed in Australia, Sweden, Finland, or the US[4, 29–31], whereas another US study found a positive association[29]. Conversely, Soriguer et al[7] found a negative association between white rice consumption and 6-year-incidence of T2DM in southern Spain. Similarly, a study among US women observed an inverse association between refined grains and T2DM[32]. The inconsistency among studies could be partly explained by differential consumption levels among diverse study populations.

The mechanism of the observed association between white rice intake and diabetes remains uncertain. In our study, rice consumption was positively associated with magnesium intake, which is known to be associated with lower T2DM risk[33]. Nevertheless, the inverse rice and T2DM association remained significant after magnesium adjustment. We also observed that higher rice consumers had higher levels of physical activity, and were more likely to live in less urbanized areas – and thus were similar in lifestyle to the early stages of the nutrition transition, a period where diabetes prevalence was lower than it is now[34]. In this sense, the lower diabetes prevalence among higher rice consumers observed in our study mimics the condition in China 20 years ago. Although we adjusted for urbanization level and physical activity, it is possible that other unmeasured factors associated with the social and nutrition transition might confound the association.

In our analyses, the inverse association between rice consumption and diabetes in the Central region was slightly attenuated comparing the fully-adjusted model to the multivariable model without BMI adjustment, indicating that the association could be partly due to the negative relationship between rice intake and BMI in this region, which is consistent with other studies[11, 14, 35]. These findings suggest that a high consumption of white rice might be linked to more healthy diets. In our study, high rice consumption was strongly correlated with a healthy low-wheat diet pattern (low wheat, high fish and seafood intake) in the Central region. Another possible reason could be the up-regulation of lipolysis and the down-regulation of lipogenesis by rice protein, which has been reported in a study in rats that showed improved adiposity and body weight after rice protein feeding[36]. In addition, fried rice is commonly consumed in China by cooling steamed rice in the refrigerator overnight and stir-frying it with oil; recent studies have shown that these processes promote rice starch retrogradation, increase the resistant starch concentration of rice and reduce the rice calories[37]. However, the inverse association remained significant after BMI and diet pattern adjustment, suggesting an independent relationship.

White rice intake and dyslipidemia

The positive association between high triglycerides and low HDL with white rice consumption in the North region confirms some previous studies[12–15, 38], whereas others found no association[5, 10]. Possible explanations for our findings could be enhanced hepatic synthesis of VLDL[39], or decreased clearance of apoB-containing particles related to reduced lipoprotein lipase activity induced by high carbohydrate intake[40, 41]. We also examined the relation between rice consumption and AD, an important risk factor for cardiovascular disease[24], and found a positive association only in the North region. Additionally, we observed a negative relationship between rice intake and high LDL prevalence in the Central region. Few studies have examined this association. One such study found no association[5], whereas an inverse relationship between total carbohydrate intake and high LDL has been reported[42]. Another study found mixed results, depending on whether high carbohydrate intake replaced saturated or polyunsaturated fat intake[43]. The association between rice consumption and LDL remains uncertain and is possibly affected by other diet components.

It is unclear why associations between rice, diabetes and dyslipidemia varied across the three regions. Studies have shown higher prevalence of metabolic syndrome in the North than South regions of China[44, 45]. The inconsistency may be due to multiple factors including differences in dietary patterns, cooking methods, and other lifestyle aspects among residents in these three regions.

Our study is not without limitations. First, the cross-sectional study design makes it difficult to establish temporality of rice consumption, diabetes, and dyslipidemia. Second, we were not able to distinguish type 1 from type 2 diabetes, but type 1 diabetes is rare in China[46]. Third, we adjusted for dietary pattern scores to control for dietary confounders. However, due to the complex correlation between foods consumed, this approach cannot completely remove the dietary confounding. As in Rebello et al[28], we conducted the substitution analysis in sensitivity analysis replacing wheat products with rice to provide additional insights regarding this issue. Fourth, the Chinese food composition table used did not include brown rice, thus we were unable to compare findings for white versus brown rice in relation to diabetes and dyslipidemia. However, brown rice is rarely consumed in China[47], and a randomized controlled trial replacing white rice with brown rice showed no effect on FBG levels among a Chinese population with diabetes or pre-diabetes[48].

Strengths of our study include population-based study sample from the national survey, allowing us to detect differences of the association across three main regions in China, and the use of detailed three 24-hour dietary recalls to quantify rice intake and adjust for dietary confounders. In addition, we used biomarkers derived from fasting blood to identify diabetes and dyslipidemia cases, which is critical given high prevalence of undiagnosed disease in this population.

In summary, our data suggest that a diet high in white rice was associated with lower prevalence of diabetes and high LDL, and higher prevalence of high triglycerides, low HDL, and AD in certain regions of China. Given that white rice is a staple food and main contributor to total energy intake in many parts of China, the role of white rice consumption in relation to diabetes and dyslipidemia is worth further exploration.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

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Table 1

Characteristics of the participants by geographic region[a] and by white rice consumption tertile

	North Region Percent energy from white rice, % (Median 30.0, IQR[b] 20.2–40.8)				Central Region Percent energy from white rice, % (Median 13.5, IQR[b] 0–31.7)				South Region Percent energy from white rice, % (Median 43.0, IQR[b] 32.4–53.5)				Across region P^d
	Tertile 1 (0–23.9)	Tertile 2 (23.9–36.9)	Tertile 3 (36.9–86.8)	P^c	Tertile 1 (0–3.5)	Tertile 2 (3.6–24.1)	Tertile 3 (24.2–87.5)	P^c	Tertile 1 (0–36.4)	Tertile 2 (36.4–49.8)	Tertile 3 (49.8–86.6)	P^c	
Median intake, % energy	16.2	30.1	45.9		0.0	13.5	39.9		27.7	43.0	57.9		
Participants, n	504	512	513		908	899	912		1106	1136	1138		
Male, %	49.3	45.1	48.7	0.33	47.5	45.2	46.7	0.60	41.7	47.3	51.8	<0.001	0.71
Age, [e] years	51.8±13.7	49.4±13.3	49.6±13.9	0.01	51.0±14.9	50.9±16.0	51.7±14.7	0.49	53.0±15.0	50.9±15.4	50.2±15.1	<0.001	0.04
BMI, kg/m^2	23.6±3.3	24.2±3.4	23.8±3.6	0.03	24.4±3.4	24.1±3.6	23.6±3.4	<0.001	23.1±3.4	22.7±3.3	22.1±3.2	<0.001	<0.001
Current smoker, %	28.7	28.9	29.9	0.90	27.5	26.1	24.2	0.24	24.9	29.6	29.9	0.01	0.04
Education, %													
Below high school	34.7	36.8	43.8		47.1	39.1	43.6		40.7	45.8	53.5		
High school	41.8	48.5	42.7	<0.001	46.7	46.1	45.5	<0.001	45.4	43.8	40.1	<0.001	<0.001
Above high school	23.5	14.7	13.5		6.2	14.8	12.7		14.0	10.3	6.4		
Income, [f] %													
Low	26.6	32.0	36.5		39.4	29.6	17.2		35.0	37.2	39.6		
Medium	33.2	35.8	35.8	<0.001	29.2	32.0	30.3	<0.001	33.1	32.2	37.7	<0.001	<0.001
High	40.2	32.2	27.7		31.4	38.4	52.5		31.9	30.6	22.7		
Urbanicity, [g] %													
Low	35.7	45.5	45.7		48.0	25.3	17.2		18.1	26.3	46.6		
Medium	20.6	25.2	29.9	<0.001	32.7	32.9	37.2	<0.001	31.6	41.0	34.0	<0.001	<0.001
High	43.7	29.3	24.4		19.3	41.8	45.6		50.3	32.7	19.4		
Hypertension, %	48.6	50.4	48.9	0.82	44.8	46.6	46.1	0.73	40.2	39.6	33.3	0.001	<0.001
Total physical activity, METS/week	240.0±203.0	259.4±215.9	295.0±242.6	<0.001	262.9±207.4	199.9±172.3	218.6±169.0	<0.001	183.1±168.0	235.3±188.4	284.6±182.6	<0.001	<0.001
Total energy, kcal/day	2151.2±578.2	2036.2±551.2	2008.0±617.8	<0.001	2074.1±679.0	2194.2±730.8	2316.3±703.0	<0.001	2159.6±751.0	2149.2±631.4	2076.8±568.5	0.004	<0.001
Fiber, g/day	13.8±6.6	11.4±4.4	10.3±5.0	<0.001	13.9±7.7	13.8±7.6	11.5±6.1	<0.001	11.7±10.2	9.8±6.1	9.0±5.2	<0.001	<0.001
Total fat, % energy from fat	33.5±9.0	31.8±8.8	26.0±8.3	<0.001	28.1±11.0	31.5±11.8	30.5±9.7	<0.001	39.9±10.9	32.1±8.7	25.1±7.4	<0.001	<0.001

	North Region Percent energy from white rice, % (Median 30.0, IQR[b] 20.2–40.8)				Central Region Percent energy from white rice, % (Median 13.5, IQR[b] 0–31.7)				South Region Percent energy from white rice, % (Median 43.0, IQR[b] 32.4–53.5)				Across region P^d
	Tertile 1 (0–23.9)	**Tertile 2 (23.9–36.9)**	**Tertile 3 (36.9–86.8)**	P^c	**Tertile 1 (0–3.5)**	**Tertile 2 (3.6–24.1)**	**Tertile 3 (24.2–87.5)**	P^c	**Tertile 1 (0–36.4)**	**Tertile 2 (36.4–49.8)**	**Tertile 3 (49.8–86.6)**	P^c	
Magnesium, mg/day	320.8±109.9	296.4±87.2	282.9±86.5	<0.001	306.7±123.7	314.1±120.7	311.3±107.0	0.38	287.1±134.7	270.5±102.5	266.2±97.6	<0.001	<0.001

[a] Geographic regions: North: Heilongjiang, Liaoning; Central: Shandong, Henan, Jiangsu; South: Hunan, Hubei, Guangxi, Guizhou.

[b] IQR: inter-quartile range.

[c] Within region *p* values.

[d] Across region *p* values.

[e] Mean ± S.D. (All such values).

[f] Per capita household income, categorized based on the cut-off values of tertiles.

[g] Estimated from urbanicity index, a multi-component scale that includes population density, economic activity, modern markets, transportation, etc. [49], categorized based on the cut-off values of tertiles.

Table 2

Factor loadings for two dietary patterns in each geographic region[a] derived from principal factor analysis and Pearson's correlation coefficients between pattern scores and food/nutrients intake

	North region		Central region		South region	
	Western pattern	**Traditional pattern**	**Low-wheat pattern**	**Western pattern**	**Western pattern**	**High-wheat pattern**
Food groups, g/day						
Wheat products as staple food[b]	**−0.27**[e]	0.18	**−0.77**	0.02	−0.05	**0.52**
Low-sugar wheat products[c]	**0.64**	0.00	0.05	**0.36**	**0.47**	**−0.20**
Whole grains[d]	0.10	**−0.22**	**−0.43**	0.14	−0.01	**−0.39**
Cakes & pastries	0.16	**0.48**	**0.40**	**0.23**	**0.50**	0.00
Starchy tubers & starch	**−0.43**	−0.19	**−0.25**	0.04	0.07	**0.28**
Fruits & vegetables	−0.13	0.12	**0.26**	0.14	**0.22**	0.15
Red meat	**0.23**	**0.33**	**0.43**	**0.38**	**0.28**	−0.14
Poultry	**0.35**	−0.08	**0.41**	**0.30**	**0.28**	**−0.37**
Fish & seafood	**0.29**	**0.35**	**0.66**	0.18	**0.37**	−0.06
Dried legumes	**0.31**	0.12	**0.27**	0.09	0.08	**0.33**
Eggs	0.02	0.00	0.01	**0.46**	**0.29**	**0.36**
Milk	**0.66**	**0.20**	**0.37**	**0.47**	**0.67**	0.05
Soymilk	0.12	**0.53**	0.07	**0.20**	**0.37**	0.05
Pattern scores, mean ± S.D.	−0.18±0.35	0.57±0.34	−0.29±0.54	1.16±0.40	0.59±0.27	0.60±0.47
Correlation coefficients						
White rice, % energy	−0.07*	−0.24*	0.64*	−0.22*	−0.27*	−0.29*
Total energy, kcal/day	−0.03	0.27*	0.03	0.28*	0.16*	0.13*
Total fat, % energy	0.23*	0.24*	0.34*	0.23*	0.22*	−0.09*

[a]Geographic regions: North: Heilongjiang, Liaoning; Central: Shandong, Henan, Jiangsu; South: Hunan, Hubei, Guangxi, Guizhou..

[b]Noodles, wheat buns etc.

[c]Biscuits, bread, dumplings.

[d]Corn and millet.

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[e] Factor loadings ≥|0.20| are bold.

* $p<0.05$.

Table 3

ORs (95% CIs) of diabetes according to categories of percent energy from white rice and geographic region[a]

	Percent energy from white rice, %			*P* – trend[b]
	Tertile 1	Tertile 2	Tertile 3	
North (total prevalence: 5.2%)				
Median intake (range), %	16.2 (0–23.9)	30.1 (23.9–36.9)	45.9 (36.9–86.8)	
Participants, n	504	512	513	
No. (%) of cases	25 (5.0)	28 (5.5)	26 (5.1)	
Fully adjusted multivariable model[c]	1.00 (reference)	1.00 (0.56, 1.81)	0.99 (0.52, 1.89)	0.98
Central (total prevalence: 5.7%)				
Median intake (range), %	0.0 (0–3.5)	13.5 (3.6–24.1)	39.9 (24.2–87.5)	
Participants, n	908	899	912	
No. (%) of cases	57 (6.3)	60 (6.7)	38 (4.2)	
Fully adjusted multivariable model[c]	1.00 (reference)	0.95 (0.63, 1.44)	0.59 (0.36, 0.99)	0.03
South (total prevalence: 3.7%)				
Median intake (range), %	27.7 (0–36.4)	43.0 (36.4–49.8)	57.9 (49.8–86.6)	
Participants, n	1106	1136	1138	
No. (%) of cases	48 (4.3)	42 (3.7)	35 (3.1)	
Fully adjusted multivariable model[c]	1.00 (reference)	0.96 (0.61, 1.49)	0.95 (0.58, 1.56)	0.83

Diabetes was defined as a fasting blood glucose measurement ≥ 7.0 mmol/L.

[a] Geographic regions: North: Heilongjiang, Liaoning; Central: Shandong, Henan, Jiangsu; South: Hunan, Hubei, Guangxi, Guizhou.

[b] Median values were assigned to each category and the variable was modeled as continuous to test linear trend.

[c] Adjusted for age (continuous with linear and quadratic terms), gender, education (below high school/high school/above high school), urbanicity (low/medium/high), hypertension diagnosis (yes/no), total physical activity (METs/week, quartiles), total energy intake (kcal/day, quartiles), fiber intake (g/day, quartiles), magnesium intake (mg/day, quartiles), dietary pattern scores (quartiles), and BMI (kg/m^2, quartiles).

Table 4

ORs (95% CIs) of dyslipidemia markers according to categories of percent energy from white rice and geographic region[a]

	Percent energy from white rice, %			*P* – trend[b]
	Tertile 1	Tertile 2	Tertile 3	
High triglycerides				
North (total prevalence: 37.2%)				
Median intake (range), %	16.2 (0–23.9)	30.1 (23.9–36.9)	45.9 (36.9–86.8)	
Participants, n	533	532	532	
No. (%) of cases	182 (34.2)	204 (38.4)	208 (39.1)	
Fully adjusted multivariable model[c]	1.00 (reference)	1.19 (0.90, 1.56)	1.46 (1.09, 1.95)	0.01
Central (total prevalence: 29.5%)				
Median intake (range), %	0.0 (0–3.5)	13.5 (3.6–24.1)	39.9 (24.2–87.5)	
Participants, n	942	941	941	
No. (%) of cases	278 (29.5)	284 (30.2)	271 (28.8)	
Fully adjusted multivariable model[c]	1.00 (reference)	1.04 (0.83, 1.30)	1.00 (0.79, 1.24)	0.97
South (total prevalence: 31.2%)				
Median intake (range), %	27.7 (0–36.4)	43.0 (36.4–49.8)	57.9 (49.8–86.6)	
Participants, n	1153	1152	1152	
No. (%) of cases	407 (35.3)	357 (30.7)	318 (27.6)	
Fully adjusted multivariable model[c]	1.00 (reference)	0.87 (0.71, 1.05)	0.87 (0.69, 1.11)	0.24
High LDL				
North (total prevalence: 30.8%)				
No. (%) of cases	175 (32.8)	150 (28.2)	166 (31.2)	
Fully adjusted multivariable model[c]	1.00 (reference)	0.86 (0.65, 1.16)	1.18 (0.87, 1.60)	0.28
Central (total prevalence: 32.7%)				
No. (%) of cases	348 (36.9)	325 (34.5)	251 (26.7)	
Fully adjusted multivariable model[c]	1.00 (reference)	0.78 (0.63, 0.97)	0.54 (0.42, 0.69)	<0.001
South (total prevalence: 30.4%)				
No. (%) of cases	352 (30.5)	367 (31.9)	331 (28.7)	
Fully adjusted multivariable model[c]	1.00 (reference)	1.20 (0.99, 1.45)	1.21 (0.94, 1.56)	0.12
Low HDL				
North (total prevalence: 31.3%)				
No. (%) of cases	147 (27.6)	176 (33.1)	176 (33.1)	
Fully adjusted multivariable model[c]	1.00 (reference)	1.20 (0.91, 1.58)	1.38 (1.03, 1.85)	0.03
Central (total prevalence: 26.3%)				
No. (%) of cases	244 (25.9)	240 (25.5)	258 (27.4)	
Fully adjusted multivariable model[c]	1.00 (reference)	0.96 (0.75, 1.22)	1.11 (0.86, 1.43)	0.32
South (total prevalence: 23.1%)				
No. (%) of cases	282 (24.5)	254 (22.1)	264 (22.9)	

	Percent energy from white rice, %			P – trend[b]
	Tertile 1	Tertile 2	Tertile 3	
Fully adjusted multivariable model[c]	1.00 (reference)	0.99 (0.79, 1.25)	1.21 (0.92, 1.59)	0.21
Atherogenic dyslipidemia				
North (total prevalence: 19.5%)				
No. (%) of cases	86 (16.1)	111 (20.9)	114 (21.4)	
Fully adjusted multivariable model[c]	1.00 (reference)	1.30 (0.93, 1.81)	1.63 (1.15, 2.31)	0.01
Central (total prevalence: 14.0%)				
No. (%) of cases	133 (14.1)	128 (13.6)	133 (14.1)	
Fully adjusted multivariable model[c]	1.00 (reference)	0.92 (0.68, 1.23)	1.04 (0.76, 1.43)	0.66
South (total prevalence: 12.8%)				
No. (%) of cases	173 (15.0)	137 (11.9)	133 (11.6)	
Fully adjusted multivariable model[c]	1.00 (reference)	0.89 (0.68, 1.16)	1.05 (0.76, 1.46)	0.86

High triglycerides: ≥150 mg/dL or taking lipid lowering medication; high LDL: >130 mg/dL or taking lipid lowering medication; low HDL: Men: <40 mg/dL, women <50 mg/dL; atherogenic dyslipidemia: high total triglycerides *and* low HDL.

[a]Geographic regions: North: Heilongjiang, Liaoning; Central: Shandong, Henan, Jiangsu; South: Hunan, Hubei, Guangxi, Guizhou.

[b]Median values were assigned to each category and the variable was modeled as continuous to test linear trend.

[c]Adjusted for age (continuous with linear and quadratic terms), gender, education (below high school/high school/above high school), urbanicity (low/medium/high), hypertension diagnosis (yes/no), total physical activity (METs/week, quartiles), total energy intake (kcal/day, quartiles), fat intake (% of total energy, quartiles), dietary pattern scores (quartiles), and BMI (kg/m^2, quartiles).