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Original Contribution

Dietary Carbohydrates, Refined Grains, Glycemic Load, and Risk of Coronary Heart Disease in Chinese Adults

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The potential long-term association between carbohydrate intake and the risk of coronary heart disease (CHD) remains unclear, especially among populations who habitually have high-carbohydrate diets. We prospectively examined intakes of carbohydrates and staple grains as well as glycemic index and glycemic load in relation to CHD among 117,366 Chinese women and men (40–74 years of age) without history of diabetes, CHD, stroke, or cancer at baseline in Shanghai, China. Diet was assessed using validated food frequency questionnaires. Incident CHD cases were ascertained during follow-ups (in women, the mean was 9.8 years and in men, the mean was 5.4 years) and confirmed by medical records. Carbohydrate intake accounted for 67.5% of the total energy intake in women and 68.5% in men. Seventy percent of total carbohydrates came from white rice and 17% were from refined wheat products. Positive associations between carbohydrate intakess and CHD were found in both sexes (all *P* for heterogeneity > 0.35). The combined multivariate-adjusted hazard ratios for the lowest to highest quartiles of carbohydrate intake, respectively, were 1.00, 1.38, 2.03, and 2.88 (95% confidence interval: 1.44, 5.78; *P* for trend = 0.001). The combined hazard ratios comparing the highest quartile with the lowest were 1.80 (95% confidence interval: 1.01, 3.17) for refined grains and 1.87 (95% confidence interval: 1.00, 3.53) for glycemic load (both *P* for trend = 0.03). High carbohydrate intake, mainly from refined grains, is associated with increased CHD risk in Chinese adults.

carbohydrates; Chinese; coronary heart disease; glycemic load; refined grains

Abbreviations: BMI, body mass index; CHD, coronary heart disease; CI, confidence interval; FFQ, food frequency questionnaire; GI, glycemic index; GL, glycemic load; SWHS, Shanghai Women's Health Study; SMHS, Shanghai Men's Health Study; WHR, waist-to-hip ratio.

Consuming a diet low in fat, particularly low in saturated fat, has been generally recommended for the prevention of coronary heart disease (CHD) (1, 2). Consequently, consumption of carbohydrates has increased substantially in many countries (3, 4). However, a recent pooled analysis of prospective cohorts from Western populations found that replacing saturated fat with carbohydrates was not effective in reducing the risk of CHD (5); the risk might be even greater if foods with high glycemic index (GI) values were used for the substitution (6). GI is an indicator of the body's glycemic response after consuming a food that contains carbohydrates compared with that after consuming a reference food (7). Generally, foods rich in rapidly absorbed carbohydrates, such as white rice and potatoes, have high GI values (8). Glycemic load (GL), which is the product of a food's GI and carbohydrate content divided by 100, has been developed as a means of capturing both the quality and quantity of dietary carbohydrates (8, 9). Clinical trials conducted over the past few decades have shown that high-carbohydrate diets significantly increase levels of fasting and postprandial glucose, insulin, and triglycerides and decrease the level of high-density lipoprotein cholesterol (10, 11), whereas reducing dietary GI or GL improves CHD risk factors, including insulin resistance, hypertriglyceridemia, high blood pressure, and inflammation (12, 13).

A few prospective cohort studies have found that a high intake of dietary carbohydrates and high GI and/or GL were associated with an elevated risk of CHD (9, 14–16), but some studies reported no association (17–19). The results appear to vary by sex, obesity status, and intake levels and food sources of carbohydrates (20, 21). To date, little is known about the relationship between carbohydrates and cardiovascular risk in Asian populations, who habitually have a high rate of carbohydrate consumption. In typical Chinese diets, carbohydrates provide 60%–70% of total energy, and the majority of carbohydrates are from processed grains, predominantly white rice in southern China (22, 23). Additionally, at the same body mass index (BMI; measured as weight in kilograms divided by height in meters squared), Asians have more body fat and visceral fat than do populations with European ancestry (24, 25), which may render Asians susceptible to insulin resistance and metabolic syndrome at a lower BMI. Also, Asians may be prone to the adverse effects of high-carbohydrate diets (26–28). Using data from the Shanghai Women's Health Study (SWHS) and the Shanghai Men's Health Study (SMHS), we investigated the long-term associations of dietary carbohydrates, white rice, and refined wheat products and dietary GI and GL with the risk of incident CHD in middle-aged and older Chinese adults.

MATERIALS AND METHODS

Study population

The SWHS and SMHS are population-based prospective cohort studies conducted in urban communities of Shanghai, China. Details of the study designs have been reported previously (29, 30). Briefly, from 1997 to 2000, all eligible women aged 40–70 years and living in the study communities were invited to participate in the SWHS ($n = 81{,}170$). Of these women, 75,221 completed an in-person interview, yielding a participation rate of 92.7%. After excluding women who were later found to be younger than 40 years of age or older than 70 years of age, the final SWHS cohort consisted of 74,941 women. Similarly, of the 83,125 eligible men aged 40–74 years at study enrollment between 2002 and 2006, a total of 61,482 were recruited and completed the baseline survey, with a participate rate of 74.1%. Information on sociodemographic characteristics, diet, lifestyle factors, physical activity habits, and medical history were collected using structured questionnaires during in-person interviews. Weight, height, and waist and hip circumferences were measured according to standard protocols at baseline. Both studies were approved by the institutional review boards of Shanghai Cancer Institute and Vanderbilt University, and written informed consent was provided by all participants.

Dietary assessment

Validated semiquantitative food frequency questionnaires (FFQs) were used to assess usual dietary intake. The FFQ used in the SWHS comprised 77 items that covered 86% of foods commonly consumed in our study population (31). A similar but extended FFQ with 81 items was used in the SMHS; it covered 89% of commonly consumed foods (32). Participants were asked about how often and in what quantities they ate each food or food group on average over the 12 months before the interview. The frequency and amount of consumption per unit of time were converted into food intake per day. Total energy and nutrient intakes were calculated based on the 2002 Chinese Food Composition Tables (22). GI values (using glucose as the referent) of carbohydrate-containing foods were extracted from both the Chinese Food Composition Tables and the International Tables of Glycemic Index and Glycemic Load Values: 2008 (33, 34). GL for each food was calculated by multiplying the available carbohydrate content of the food by its GI. Dietary GL for each participant was estimated by first multiplying the GL for each food by the amount of consumption and then summing the GL values from all foods. Overall dietary GI was obtained by dividing the dietary GL by the total available carbohydrate intake. Carbohydrate-rich foods mentioned in our FFQs included rice and wheat products (wheat noodles, steamed bread, pastries, and bread). Previous validation studies revealed good correlations between estimates of dietary intakes from the FFQs and multiple 24-hour dietary recalls, with correlation coefficients in the SWHS and SMHS equal to 0.66 and 0.64 for carbohydrates, 0.60 and 0.49 for protein, 0.59 and 0.38 for fat, and 0.66 and 0.63 for staple grains, respectively (31, 32).

Outcome ascertainment

The primary outcomes of the present study included incident nonfatal myocardial infarction and fatal CHD identified via home visits every 2–3 years. Medical records for participants who reported a diagnosis of myocardial infarction were sought and reviewed by physicians who were unaware of the participant's exposure status. A case of myocardial infarction was confirmed if it met the diagnostic criteria of the World Health Organization: symptoms of myocardial infarction plus either diagnostic electrocardiographic changes or elevated levels of cardiac enzymes (35). Self-reported but unconfirmed myocardial infarction cases were considered censoring events. Deaths were identified through annual linkages to the Shanghai Vital Statistics Registry (>99% complete). Fatal CHD was confirmed by review of medical records whenever possible and death certificates with CHD listed as the underlying cause of death (*International Classification of Diseases, Ninth Revision*, codes 410–414). The overall follow-up rates were 92.3% in the SWHS and 93.8% in the SMHS. Follow-up time was calculated from the date of baseline interview to the date of diagnosis of incident CHD, death, loss of follow-up, or December 30, 2009, whichever came first.

Statistical analysis

For the present analysis, we excluded 9,980 women and 8,785 men who had a history of diabetes, CHD, stroke, or cancer at recruitment (history of cancer was an exclusion criterion for enrollment in the SMHS). We further excluded 107 women and 185 men who reported extreme energy intakes (>3,500 or <500 kcal/day for women and >4,200 or <800 kcal/day for men). After these exclusions, a total of 64,854 women and 52,512 men were finally analyzed.

We first performed analyses separately for each cohort and then conducted meta-analyses using a fixed-effects model to combine risk estimates for men and women. We chose meta-analysis rather than simple pooling methods because the former could account for the differences between the 2 cohorts in baseline characteristics of participants, time period of recruitment, and duration of follow-up. All dietary intakes were adjusted for total energy intakes by using the residual method (36). Participants were classified into quartiles of daily intakes of carbohydrates, rice, and wheat products and of dietary GI and GL. Cox proportional regression models were applied to estimate hazard ratios and 95% confidence intervals using age as the timescale and were stratified by birth cohort (5-year intervals). Covariates included educational level (4 levels), income (4 levels), cigarette smoking (for women, never or ever; for men, never, past, or current, with current subclassified as 1–9, 10–19, or ≥20 cigarettes/day), alcohol consumption (never, past, or current, with current subclassified as <1, 1–1.99, 2–2.99, or ≥3 drinks/day), physical activity level (quartile of metabolic equivalent scores) (37), waist-to-hip ratio (WHR), history of hypertension, and dietary intakes of total energy (kcal/day), saturated fat (g/day), and protein (g/day). Tests for trend were examined by treating the median values of each quartile as a continuous variable. In addition to the residual method, nutrient-density models and partition models were also applied. Stratified analyses were performed to explore potential effect modifications by age, educational attainment, obesity, physical activity level, smoking status, and history of hypertension. Sensitivity analyses were conducted by omitting the first year of follow-up. All statistics were performed using SAS software, version 9.3 (SAS Institute, Inc., Cary, North Carolina), and 2-sided P values < 0.05 were considered statistically significant.

RESULTS

The mean carbohydrate intakes were 281 (standard deviation, 27) g/day in women and 316 (standard deviation, 34) g/day in men, accounting for 68.5% (standard deviation, 6.8) and 67.5% (standard deviation, 7.2) of total energy, respectively. In both cohorts, compared with participants with low carbohydrate intakes, those with high intakes were older and had higher BMIs and WHRs but lower income and educational levels. They were less likely to drink alcohol and more likely to have a history of hypertension (Table 1). Intakes of saturated fat and protein decreased with increasing carbohydrate intake (Table 2).

During a mean follow-up of 9.8 years in SWHS and 5.4 years in SMHS, 120 women and 189 men were confirmed as having developed incident CHD. Higher carbohydrate intake was associated with increased risk of CHD in both sexes (Table 3). No significant heterogeneity was observed between men and women (all P for heterogeneity > 0.35). Comparing the highest quartile of carbohydrate intake with the lowest, the age- and total energy–adjusted hazard ratios for CHD were 1.56 (95% CI: 0.91, 2.66) in women, 1.47 (95% CI: 0.98, 2.22) in men, and 1.50 (95% CI: 1.08, 2.08) for men and women combined (P for trend = 0.005). In multivariate models that were controlled for age, income, educational level, smoking status, alcohol consumption, physical activity level, WHR, history of hypertension, and total energy intake, the combined hazard ratio for the highest quartile versus the lowest was 1.34 (95% CI: 0.96, 1.88; P for trend = 0.04). With additional control for protein intake (evaluating the effect of substituting carbohydrates for fat while keeping total energy constant), the combined hazard ratio for the highest quartile versus the lowest was 1.96 (95% CI: 1.15, 3.33; P for trend = 0.006). However, after controlling for fat (evaluating the effect of substituting carbohydrates for protein while keeping total energy constant), the combined hazard ratio for the highest quartile versus the lowest was 2.96 (95% CI: 1.59, 5.53; P for trend = 0.0003). With control for both saturated fat and protein intakes, the combined hazard ratio for the highest quartile versus the lowest was 2.88 (95% CI: 1.44, 5.78; P for trend = 0.001).

White rice and refined wheat products contributed 70% (standard deviation, 15) and 17% (standard deviation, 13) of total carbohydrates, respectively. When added together, they showed a significant association with CHD risk in both men and women (for the highest quartile vs. the lowest, combined hazard ratio = 1.80, 95% CI: 1.01, 3.17; P for trend = 0.03) (Table 3). Positive associations of dietary GL with incident CHD were also found in both men and women (Table 4), with a combined hazard ratio of 1.87 (95% CI: 1.00, 3.53) for the highest quartile versus the lowest (P for trend = 0.03). However, dietary GI was not associated with risk of CHD (for the highest quartile vs. the lowest, combined hazard ratio = 1.17, 95% CI: 0.81, 1.69; P for trend = 0.48) (Table 4).

In stratified analyses, we found similar positive associations between carbohydrate intakes and risk of CHD across subgroups defined by age, BMI, or WHR. The positive association seemed stronger in participants who were physically inactive, were less educated, had ever smoked, or had a history of hypertension, but none of tests for multiplicative interactions were significant (data not shown).

We found similar results in analyses using nutrient-density models: Higher percentages of energy derived from carbohydrates and refined grains were associated with higher risk of CHD (for the highest quartile of carbohydrates vs. the lowest, combined hazard ratio = 3.05, 95% CI: 1.50, 6.23; P for trend = 0.0001 and for the highest quartile of refined grains vs. the lowest, combined hazard ratio 1.86, 95% CI: 1.04, 3.34; P for trend = 0.04). In the analyses using partition models that included fat and protein intakes without controlling for total energy, the combined hazard ratios for the highest quartile versus the lowest were 1.20 (95% CI: 0.81, 1.77) for carbohydrate intake (P for trend = 0.74) and 1.12 (95% CI: 0.78, 1.61) for refined grains intake (P for trend = 0.40). In sensitivity analyses that excluded the first year of follow-up, results remained unchanged, with a combined hazard ratio of 3.34 (95% CI: 1.63, 6.84) for carbohydrate intake in the highest quartile versus the lowest (P for trend = 0.0004).

DISCUSSION

Among middle-aged and older Chinese adults who were free of diabetes, CHD, stroke, and cancer at baseline, we found that higher carbohydrate intake (mainly from white rice and refined wheat products) and dietary GL were associated with an increased risk of CHD in both women and men. These associations were robust and independent of several known CHD risk factors, including socioeconomic status, central obesity, smoking status, hypertension, and saturated fat intake.

Diets rich in refined carbohydrates may cause multiple cardiometabolic disorders (10). Refined carbohydrates can provoke

Table 1. Baseline Characteristics by Quartile of Dietary Carbohydrate Intake in the Shanghai Women's Health Study (1997–2000) and Shanghai Men's Health Study (2002–2006)*

Characteristic	Quartile of Dietary Carbohydrate Intake							
	1		2		3		4	
	Mean	%	Mean	%	Mean	%	Mean	%
Shanghai Women's Health Study (n = *64,854*)								
Carbohydrate intake, g/day	<264		264–282		282–299		>299	
Age, years	49.9		50.7		51.4		54.1	
Body mass index[a]	23.4		23.6		23.8		24.5	
Waist-to-hip ratio	0.8		0.8		0.8		0.8	
Physical activity level, metabolic equivalent hours/week	104.0		105.9		107.5		111.5	
High income[b]		22.2		19.8		17.0		12.7
High educational level[c]		18.5		15.7		13.3		7.2
Ever smoked		2.6		2.0		2.2		3.5
Ever consumed alcohol		3.4		2.1		1.9		1.8
History of hypertension		15.6		17.6		19.3		23.7
Shanghai Men's Health Study (n = *52,512*)								
Carbohydrate intake, g/day	<296		296–319		319–339		>339	
Age, years	53.4		54.1		54.3		54.7	
Body mass index[a]	23.5		23.6		23.6		23.7	
Waist-to-hip ratio	0.9		0.9		0.9		0.9	
Physical activity, metabolic equivalent hours/week	57.1		58.4		59.4		61.7	
High income[b]		12.7		11.3		9.2		6.0
High educational level[c]		26.4		27.1		22.8		15.0
Smoking status								
Never		25.6		30.5		31.1		29.2
Past		8.3		9.2		9.6		9.7
Current		66.1		60.3		59.3		61.1
Alcohol consumption								
Never		52.5		65.5		70.2		75.4
Past		2.8		3.4		3.6		4.5
Current		44.6		41.1		26.3		20.0
History of hypertension		22.2		24.2		25.8		27.0

* $P < 0.0006$.
[a] Weight (kg)/height (m)^2.
[b] High income was defined as a family income greater than 30,000 Yuan per year for women or a personal income greater than 2,000 Yuan per month for men.
[c] High educational level was defined as having a professional or college degree or higher.

a rapid postprandial increase in blood glucose and a substantial release of insulin. Shortly thereafter, the glucose level falls, often into the hypoglycemic range (8). Lack of circulating metabolic fuels then triggers lipolysis and may also stimulate hunger and food intake (8, 38). A meta-analysis of 60 clinical trials concluded that isoenergetic substitution of carbohydrates for fatty acids elevated serum triglyceride levels and reduced high-density lipoprotein cholesterol levels (11). Later clinical trials with larger sample sizes and longer durations confirmed and extended these results by finding that low- to moderate-carbohydrate diets or low-GI diets were effective in helping people lose or maintain body weight and improve insulin resistance, blood pressure, blood lipids, and inflammatory markers (12, 13, 39–44). Our previous analysis and other studies have reported that high consumption of refined carbohydrates was associated with type 2 diabetes mellitus (23, 28), the metabolic syndrome (45), and chronic inflammation (46), all of which are strong predictors of future coronary events. Taken together, evidence from interventional and observational studies supports the adverse association of a high intake of refined carbohydrates with the development of CHD.

In the present study, participants in the highest quartile of carbohydrate intake or dietary GL had a nearly 2-fold increased risk of CHD compared with those in the lowest quartile. In

Table 2. Mean Levels of Energy-adjusted Dietary Intakes by Quartile of Carbohydrate Intake in the Shanghai Women's Health Study (1997–2000) and Shanghai Men's Health Study (2002–2006)

Dietary Component	Quartile of Carbohydrate Intake			
	1	2	3	4
	Shanghai Women's Health Study			
Total energy, kcal/day	1,705	1,680	1,663	1,688
Glycemic index	75	77	78	79
Glycemic load	181	206	220	248
Refined rice and wheat, g/day	255	299	324	363
Saturated fat, g/day	12	9	7	5
Protein, g/day	77	68	62	54
	Shanghai Men's Health Study			
Total energy, kcal/day	1,947	1,917	1,923	1,933
Glycemic index	78	79	80	81
Glycemic load	209	239	260	289
Refined rice and wheat, g/day	302	355	386	430
Saturated fat, g/day	14	11	9	6
Protein, g/day	91	79	73	64

the Nurses' Health Study, total carbohydrate intake was shown to have a marginally significant association with CHD (for women in the highest quintile of intake vs. the lowest, relative risk = 1.23, 95% CI: 0.86, 1.75); however, a significant association was found for dietary GL (for women in the highest quintile vs. the lowest, relative risk = 1.98, 95% CI: 1.41, 2.77) (9). Among European populations, dietary GI/GL was found to be associated with incident CHD in Italian and Dutch women (14, 15) but not in Italian men or Swedish men and women (15, 18, 19). Recent meta-analyses summarized these mixed results and suggested a modest association between dietary GL and CHD, with a 30% increased risk in the highest consumption group, although the association seemed to be significant only in women and was more pronounced in overweight individuals (21, 47). Notably, the average carbohydrate intake in our study population was about 50% higher than that in most Western populations (approximately 300 g/day vs. 200 g/day and contributing 70% vs. 50% of daily energy) (21, 48). Moreover, carbohydrates in our population were predominantly from a single food source, that is, white rice, which primarily consists of refined starch and has a high GI value (GI = 64–83 using glucose as the referent) (28, 33). In a Japanese cohort, the average intakes of raw white rice were 170 g/day in women and 180 g/day in men. In that study, white rice intake was found to be inversely associated with death from cardiovascular disease in men but not in women (49). The reasons for the apparent conflicting results between that study and ours are not clear. It is possible that differences in the baseline characteristics of the study populations, covariates, and end points evaluated may explain some of the inconsistencies between studies. Compared with the findings for CHD, that for the association between carbohydrate intake and type 2 diabetes mellitus appeared to be more consistent across studies. A meta-analysis showed

Table 3. Risk of Coronary Heart Disease by Intake of Carbohydrates and Refined Rice/Wheat Products in the Shanghai Women's Health Study and Shanghai Men's Health Study, 1997–2009

Quartile of Intake	Women						Men						Combined	
	Median intake, g/day	No. of Cases	Age- and Energy-adjusted Model		Multivariate-adjusted Model[a]		Median intake, g/day	No. of Cases	Age- and Energy-adjusted Model		Multivariate-adjusted Model[a]		Multivariate-adjusted Model[a]	
			HR	95% CI	HR	95% CI			HR	95% CI	HR	95% CI	HR	95% CI
Carbohydrates[b]														
1	250	19	1.00	Referent	1.00	Referent	278	37	1.00	Referent	1.00	Referent	1.00	Referent
2	274	21	0.98	0.53, 1.82	1.19	0.56, 2.53	308	41	1.04	0.67, 1.63	1.50	0.85, 2.66	1.38	0.88, 2.18
3	290	31	1.31	0.74, 2.33	1.76	0.73, 4.25	329	51	1.28	0.84, 1.95	2.22	1.12, 4.41	2.03	1.18, 3.49
4	311	49	1.56	0.91, 2.66	2.41	0.77, 7.57	353	60	1.47	0.98, 2.22	3.20	1.33, 7.68	2.88	1.44, 5.78
P_{trend}				0.05		0.10				0.04		0.006		0.001
White rice and refined wheat products[b]														
1	253	18	1.00	Referent	1.00	Referent	306	42	1.00	Referent	1.00	Referent	1.00	Referent
2	297	20	0.98	0.52, 1.86	0.97	0.49, 1.93	354	41	0.97	0.63, 1.49	1.15	0.69, 1.90	1.08	0.72, 1.63
3	327	33	1.41	0.79, 2.51	1.41	0.69, 2.90	388	45	1.07	0.70, 1.63	1.38	0.76, 2.51	1.39	0.88, 2.21
4	367	49	1.54	0.89, 2.66	1.53	0.64, 3.68	430	61	1.45	0.98, 2.14	2.01	0.96, 4.23	1.80	1.01, 3.17
P_{trend}				0.06		0.25				0.05		0.05		0.03

Abbreviations: CI, confidence interval; HR, hazard ratio.

[a] The Cox proportional hazard model was stratified by birth cohort (5-year intervals) and adjusted for educational level, income, smoking status, alcohol consumption, physical activity level, waist-to-hip ratio, history of hypertension, and dietary intakes of total energy, saturated fat, and protein.

[b] Dietary intakes were adjusted for energy intake using the residual method.

Table 4. Risk of Coronary Heart Disease by Dietary Glycemic Index and Glycemic Load in the Shanghai Women's Health Study and Shanghai Men's Health Study, 1997–2009

Quartile of Intake	Women						Men						Combined	
	Median	No. of Cases	Age- and Energy-adjusted Model		Multivariate Model[a]		Median	No. of Cases	Age- and Energy-adjusted Model		Multivariate Model[a]		Multivariate Model[a]	
			HR	95% CI	HR	95% CI			HR	95% CI	HR	95% CI	HR	95% CI
Glycemic index[b]														
1	74	20	1.00	Referent	1.00	Referent	77	50	1.00	Referent	1.00	Referent	1.00	Referent
2	77	26	1.13	0.63, 2.02	1.05	0.58, 1.90	79	45	0.96	0.64, 1.44	0.95	0.62, 1.44	0.98	0.69, 1.38
3	79	26	1.01	0.56, 1.82	0.93	0.50, 1.71	81	42	0.94	0.62, 1.42	0.92	0.59, 1.45	0.92	0.64, 1.33
4	81	48	1.46	0.86, 2.49	1.24	0.68, 2.28	82	52	1.23	0.84, 1.82	1.13	0.71, 1.80	1.17	0.81, 1.69
P_{trend}				0.17		0.53				0.40		0.71		0.48
Glycemic load[b]														
1	177	18	1.00	Referent	1.00	Referent	205	39	1.00	Referent	1.00	Referent	1.00	Referent
2	202	22	1.07	0.58, 2.00	1.01	0.50, 2.04	234	40	1.00	0.64, 1.56	1.30	0.76, 2.24	1.18	0.77, 1.82
3	219	33	1.40	0.79, 2.49	1.28	0.58, 2.79	254	52	1.32	0.87, 2.00	1.95	1.03, 3.70	1.65	1.00, 2.70
4	241	47	1.46	0.84, 2.53	1.25	0.46, 3.42	280	58	1.44	0.96, 2.17	2.44	1.08, 5.51	1.87	1.00, 3.53
P_{trend}				0.12		0.60				0.04		0.02		0.03

Abbreviations: CI, confidence interval; HR, hazard ratio.

[a] The Cox proportional hazard model was stratified by birth cohort (5-year intervals) and adjusted for educational level, income, smoking status, alcohol consumption, physical activity level, waist-to-hip ratio, history of hypertension, and dietary intakes of total energy, saturated fat, and protein.

[b] Glycemic index and glycemic load were energy-adjusted using the residual method.

that white rice consumption was more strongly associated with an elevated risk of type 2 diabetes mellitus in Asian populations that it was Western populations (28). For a given BMI, Asian populations have higher levels of visceral fat and insulin resistance than do populations of European ancestry (24, 25). It is plausible that high consumption of refined carbohydrates may be particularly detrimental for Asian populations, who are likely to be classified as "metabolically obese" (26, 27).

As with most nutritional epidemiologic studies, dietary measurement errors are an important concern and may come from both the FFQ assessment and food composition tables. Rice and wheat products are consumed as staple foods in China and are listed as the first food items in our FFQ. The validity and reproducibility of our FFQs for assessing intakes of carbohydrates and staple foods are fairly high (31, 32). However, the validity of GI and GL assessment was not evaluated. The GIs of white rice and wheat products may vary widely by botanical variety or cooking preference (34). GIs estimated based on the International Tables of Glycemic Index and Glycemic Load Values may not be representative of local foods consumed in Shanghai. Thus, misclassification in dietary GI/GL is a concern, which may have reduced the statistical power of the study and led to underestimation of the associations.

Another concern for observational studies is possible confounding from both nondietary and dietary factors. To control for the confounding effects, we have adjusted for an extensive set of established CHD risk factors, including socioeconomic status, smoking status, WHR, and history of hypertension. In addition, we found no significant interactions between carbohydrates/high GL foods and known CHD risk factors. However, because dietary factors are correlated with each other, we cannot entirely separate the effect of dietary carbohydrates and staple foods from those of other nutrients and foods and cannot rule out the presence of residual confounding. Another limitation of our study is the relatively small number of cases, which led to relatively wide confidence intervals around risk estimates.

Our results provide new evidence on the adverse association between refined carbohydrates and incident CHD among Chinese adults who habitually have high-carbohydrate diets. Strengths of our study include the population-based prospective design and the availability of detailed information on a wide range of potential confounders. The dietary assessment was conducted through in-person interviews by using validated FFQs. The diagnosis of CHD was verified through a review of medical records. The results were consistent regardless of the approaches used for energy adjustment and were robust in stratified and sensitivity analyses. In conclusion, to our knowledge, our study is the first to find found that higher dietary carbohydrate intake, mainly in the form of refined carbohydrates from white rice and refined wheat products, was associated with a higher risk of CHD in Chinese adults.

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