Original Article

Relationship between carbohydrate intake and risk factors for cardiovascular disease in Chinese adults: data from the China Health and Nutrition Survey (CHNS)

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Background and Objectives: It is well known that dietary factors affect the development of cardiovascular disease. We evaluated the associations between carbohydrate intake and cardiovascular disease risk factors using data from the China Health and Nutrition Survey, 2009. **Methods and Study Design:** A total of 6,648 Chinese adults aged 18-60 were divided into five groups based on carbohydrate intake (% of energy). Mixed-effect linear regression models were used to estimate the risk factors in relation to carbohydrate intake, and mixed-effect logistic regression models were used to assess the risk of cardiovascular disease. **Results:** When age was adjusted, carbohydrate intake was negatively correlated with total cholesterol and triglycerides in men and total cholesterol and low-density lipoprotein cholesterol in women. However, there were positive associations of carbohydrate intake with waist circumference, body mass index, and blood pressure in women. After additional adjustment for urbanicity index, income, physical activity, education, alcohol and smoking, and dietary intake, the 5th quintile of carbohydrate intake reduced the risk for high low-density lipoprotein cholesterol in women (OR=0.73, 95% CI: 0.53, 0.99) compared with the 1st quintile. However, the top quintile of carbohydrate intake increased the risk for impaired glucose tolerance in men (OR=2.08, 95% CI: 1.04, 4.16) compared with the lowest quintile after adjusting for all confounders. **Conclusions:** Higher-carbohydrate diets may associate with risk factors for cardiovascular disease. Moderate carbohydrate intake is recommended for daily consumption. These results suggest that improving dietary patterns may be an important approach to the prevention of cardiovascular disease in Chinese adults.

Key Words: cardiovascular disease, carbohydrate intake, risk factors, Chinese, adults

INTRODUCTION

Cardiovascular disease (CVD) is a global epidemic. Estimated CVD deaths are 17.7 million globally,[1] and the death rate caused by CVD is greater than 75% in middle-income and low-income countries.[2] In China, CVD has become a leading cause of morbidity and mortality, and deaths from CVD account for more than 40% of total mortality.[2] The morbidity of CVD is increasing rapidly, and the estimated economic burden caused by CVD was 550 million dollars from 2005 to 2015.[3]

For cardiovascular health, the American Heart Association recognizes smoking, total cholesterol, fasting blood glucose and blood pressure as four cardiovascular health factors and smoking, body mass index, physical activity and diet as four cardiovascular health behaviors.[4] Overweight, diabetes mellitus, hypertension, smoking, physical inactivity, and dyslipidemia are well-established modifiable risk factors for CVD.[5-7]

Dietary pattern is a crucial factor in the development of CVD. Dietary pattern characteristics vary among countries. The high-carbohydrate diet consumed by people from low-income and middle-income countries might increase the risk of CVD and total mortality.[8] A high intake of carbohydrates increases blood pressure and apolipoprotein B-to-apolipoprotein A1 ratios and induces lower HDL cholesterol and higher triglycerides.[8-10] By contrast, low carbohydrate intake has been shown to reduce body weight and improve risk factors for CVD.[11]

A few studies have investigated the relationship between dietary carbohydrates (% of energy) and CVD risk factors in America and Korea,[12,13] but the association between risk factors for CVD and carbohydrate intake in

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the Chinese population remains unclear.

Chinese people traditionally consume large amounts of white bread and white rice as staple foods, defined as a high-carbohydrate diet. The goal of the study was to investigate the associations between risk factors for CVD and carbohydrate intake in Chinese adults.

METHODS

Study design and population

The data were obtained from the China Health and Nutrition Survey (CHNS), which used a multistage, random cluster sampling process to select samples from 15 provinces in China. The sample scheme is reported in details elsewhere.[14] Fasting blood was first collected in 2009. The information was collected by trained interviewers in order to assure compliance and quality of data.

Our analysis used one round of survey data on the participants from 2009. Participants who had incomplete information on anthropometric, biochemical, sociodemographic, or health-related factors (N=32) or implausible intakes of energy, including total energy of <800 kcal or >6000 kcal daily for men and <600 kcal or >4000 kcal daily for women (N=25), were excluded.[15] In addition, individuals taking medication for hypertension and dyslipidemia, and subjects who were told by a physician that they had heart attack or stroke, or diabetes or taking insulin (N=201) and pregnant or lactating women (N=45) were excluded. Therefore, there were 6,648 participants (3,169 men and 3,479 women) in the final data analysis. A flowchart of the selection process of the study population is shown in Figure 1.

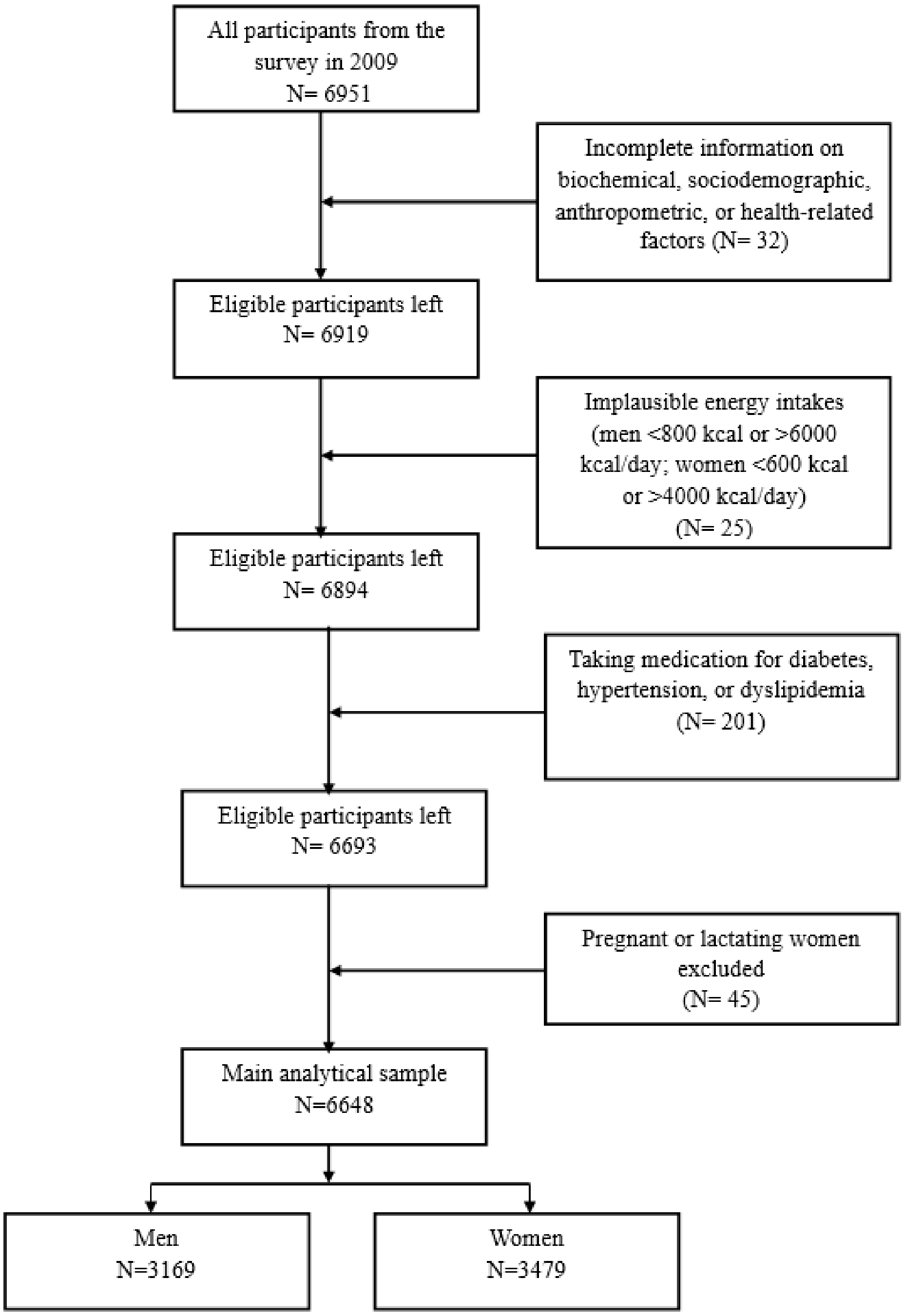

Figure 1. Selection process for the study population in the 2009 CHNS survey

Ethics approval and consent to participate
The data in this study were from CHNS. The Institutional Review Committees of the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health, the Chinese Center for Disease Control and Prevention, approved the survey protocols and instruments. Informed consent in writing was given by all participants for their participation.

Data collection and dietary assessment
There were five parts of the data in the survey: sociodemographic characteristics (such as gender, age, education, and living area); health-related behaviors (such as alcohol intake, physical activity, smoking status); laboratory measurements (such as serum cholesterol and triglycerides); physical measurements (such as blood pressure, waist circumference, weight and height) and three-day dietary intake information. All investigators were trained and followed the same questionnaire instructions.

Height and weight were measured using standardized techniques and calibrated equipment, with no shoes and light clothing worn by individuals. The weight (kg) was divided by the square of height (m^2) to determine the body mass index (BMI). Workers measured the waist circumference (WC) with a SECA tape between the iliac crest and lowest rib. Standard methods were used to measure blood pressure three times after the participant had rested for at least 10 minutes in the seated position. The average measurements of blood pressure were used for the analysis. After overnight fasting for at least 8-10 hours, workers collected blood samples in the morning. Laboratory measurements involved hemoglobin A1c (HbA1C) and four items of blood lipids, including triglycerides (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C), which were analyzed in a certified clinical laboratory.

Three-day, 24-h dietary recalls were used to assess the dietary intake of each participant. The quantity and types of food and beverages consumed during the past 24 h were reported.[16] Interviewers measured dietary intake with picture aids and food models in the household interview. The collected data for total energy intake (kcal), grains and cereals (g), vegetables and fruits (g) and carbohydrate intake (g) were calculated by using the China Food Composition Table.[17] The carbohydrate intakes were categorized into five quintiles separately by gender in the present study. The reference group defined the lowest quintile of carbohydrate intake.

Assessment of other covariates
Sociodemographic variables and health-related variables were obtained by a general questionnaire. Annual household income was divided by household size to calculate the per capita annual family income, which was classified as low, medium, and high. Education levels were separated into tertiles: non/primary school, middle school, and high school and higher.

Physical activity included four domains: transportation activities, occupational activities, leisure time, and household chores. Physical activity was measured by metabolic equivalent of task (MET) hours in each week, which were converted by the time spent in each activity. The urbanicity index of the community, as a complicated indicator of urbanization, reflected the diversity of the society, economy, infrastructure, and demography at the community level.[16]

Other covariates that were defined in the models included age (years), alcohol consumption and smoking status.

Definition of CVD risk factors
CVD risk factors were used in the study according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III).[18] BMI ≥28 kg/m^2 indicated general obesity, and WC ≥90 cm in men and ≥85 cm in women indicated central obesity.[19] Hypertension was defined as diastolic blood pressure (DBP) ≥90 mm Hg and/or systolic blood pressure (SBP) ≥140 mm Hg.[20] HbA1C ≥6.5% was defined as diabetes mellitus.[21] The cut-off values used were TG ≥200 mg/dL, TC ≥240 mg/dL, LDL-C ≥160 mg/dL, and HDL-C <40 mg/dL in men and <50 mg/dL in women.[22]

Statistical analysis
There were five quintiles of carbohydrate intake at baseline. Means and standard deviation were presented for normal distribution of continuous variables, and median (P_{25}, P_{75}) were indicated for non-normal distribution of continuous variables. Percentages were reported for categorical variables. One-way analysis of variance (ANOVA) and Mann-Whitney U test were used to test normal and non-normal distribution of the continuous variables, and chi-square tests were used to test categorical variables, in order to analyze the differences between the five carbohydrate intake (% of energy) levels. The prevalence of CVD risk factors were standardized, including general obesity/central obesity, hypertension, diabetes mellitus, hypercholesterolemia and hypertriglyceridemia.

Linear regression models were constructed to examine the relationships between BMI, WC, SBP, DBP, HbA1C, TC, HDL-C, LDL-C, TG and carbohydrate intake (% of energy), and logistic regression models were used to analyze the risk factors of CVD. Regression coefficients with 95% confidence intervals (CIs) and odds ratios (ORs) with 95% CIs were determined by gender. Four models were assessed: (1) adjusted for age; (2) additionally adjusted for physical activity, level of education, smoking status, urbanicity index, income, and alcohol consumption; (3) additionally adjusted for dietary intake, including total energy intake, grains and cereals, vegetables and fruits (rich in dietary sugar and fiber) , in order to investigate whether the relationship of carbohydrate intake to CVD risk factors was affected by sugar or fiber intake; (4) additionally adjusted for BMI. Furthermore, the quintiles of carbohydrate intake (% of energy) were evaluated by linear trends, and this variable was entered in the regression model as a continuous term. The goodness of fit, effect modifier, and potential confounders between models were examined by likelihood ratio tests.

All tests of significance were two-tailed, and *p* values <0.05 were considered significant. All data were analyzed with SAS (version 9.2, SAS Institute Inc., NC).

Table 1. General Characteristics of participants by carbohydrate intake (% energy) by gender

Characteristics	Men					*p*	Women					*p*
	Q1	Q2	Q3	Q4	Q5		Q1	Q2	Q3	Q4	Q5	
Carbohydrate intake (% energy)†	37.1 (31.9, 40.5)	47.0 (45.1, 48.8)	53.7 (52.1, 55.1)	59.8 (57.9, 61.6)	68.2 (65.7, 71.7)	<0.001	38.5 (34.2, 41.8)	47.7 (45.9, 49.7)	54.3 (52.7, 55.5)	60.0 (58.3, 61.8)	68.8 (66.1, 72.3)	<0.001
Age (years)‡	47.1±0.5	45.8±0.5	45.7±0.5	45.4±0.5	45.8±0.5	0.119	45.6±0.5	46.5±0.4	46.7±0.4	47.3±0.4	46.0±0.4	0.050
Income tertiles (%)						<0.001						<0.001
Low	20.6	26.7	32.2	37.5	43.5		21.3	30.3	36.2	37.3	46.8	
Medium	33.7	34.8	33.0	32.5	35.2		34.5	30.4	30.7	37.3	32.0	
High	45.7	38.5	34.8	30.0	21.3		44.2	39.3	33.1	25.4	21.2	
Education (%)						<0.001						<0.001
None/primary	20.0	19.8	24.4	30.1	33.5		32.1	37.3	40.9	48.8	53.2	
Middle school	38.8	42.8	45.6	46.4	44.9		32.7	34.4	36.1	33.5	36.0	
High school+	41.2	37.2	30.0	23.5	21.6		35.2	28.3	23.0	17.7	10.8	
Physical activity (MET hours/week)	182±6	205±8	229±8	274±9	299±10	<0.001	188±6	210±8	229±8	269±9	321±10	<0.001
Current smoker (%)	65.3	62.7	61.8	63.1	58.6	0.169	2.6	2.7	3.3	4.0	3.7	0.494
Alcohol consumption (%)	71.5	66.9	64.4	57.3	58.7	<0.001	14.8	10.2	7.9	6.8	6.5	<0.001
Urbanicity index	75.3±0.7	71.2±0.7	68.0±0.7	62.5±0.8	55.6±0.7	<0.001	77.7±0.6	71.3±0.7	68.7±0.7	61.7±0.7	55.3±0.6	<0.001
Dietary intake												
Total energy (Kcal/day)	2538±30	2494±28	2452±26	2486±27	2351±28	<0.001	2084±24	2061±23	2069±22	2064±23	2032±24	<0.001
Grains and cereals	380±6	420±6	448±6	504±7	550±7	<0.001	316±5	340±5	373±5	409±5	472±6	<0.001
Vegetables and fruits	379±8	402±8	396±8	397±8	401±8	0.020	386±7	384±7	405±8	384±8	388±8	0.240
BMI	23.6±0.1	23.6±0.1	23.4±0.1	23.3±0.1	23.2±0.1	0.109	23.2±0.1	23.2±0.1	23.3±0.1	23.7±0.1	23.6±0.1	0.007

Q: quintiles; MET: metabolic equivalent of task; BMI: body mass index

†Median; interquintile range in parentheses.

‡Mean±SD (all such values). Adjust by age for total energy intake, physical activity and adjusted by age and total energy intake for other relevant food groups. ANOVA or ANCOVA tests were used for continuous variables, and chi-square tests were used for categorical covariates.

RESULTS

General characteristics of the study subjects

The general characteristics of the participants across the five levels of carbohydrate intake (% of energy) by gender are shown in Table 1. Median intakes of carbohydrate in men were slightly lower than those in women in each quintile. Increasing intake of carbohydrates was associated with a lower proportion of alcohol consumption in both men and women. A higher intake of carbohydrates (% of energy) in both men and women was associated with higher levels of physical activity and living in communities with a lower degree of urbanicity. A lower intake of total energy and higher intake of grains and cereals were related to higher carbohydrate intake (% of energy) in both men and women.

Prevalence of CVD Risk Factors

The prevalence of CVD risk factors by gender are shown in Figure 2. When gender analyzed separately, men with higher carbohydrate intake (4th quintile) had higher prevalence of obesity, but lower prevalence of hypercholesterolemia than the 2nd quintile. Moreover, the prevalence of diabetes mellitus in the top quintile of carbohydrate intake was significantly lower compared with those in the lowest carbohydrate intake in men ($p<0.05$). In women, the prevalence of hypercholesterolemia in the higher carbohydrate intake (4th quintile) was lower than those in the 1st, 2nd and 3rd quintiles. Women who consumed the highest carbohydrate intake (5th quintile) had significantly lower prevalence of hypercholesterolemia compared with the 2nd quintile ($p<0.05$).

Association between carbohydrate intake and CVD risk factors

The associations between cardiovascular risks and the five levels of carbohydrate intake for the men and women are presented in Table 2 and Table 3. The associations in both men and women persisted but were attenuated after all additional adjustments. The top quintile of carbohydrate intake was negatively correlated with TC and TG compared with those with the lowest carbohydrate intake in men when adjusted for age only. Men with highest carbohydrate intake (>68.2% of energy) showed a significant decrease in TC of -5.97 (95% CI: -10.37, -1.57) after additional adjustment for income, urbanicity index, smoking status, educational level, physical activity and alcohol

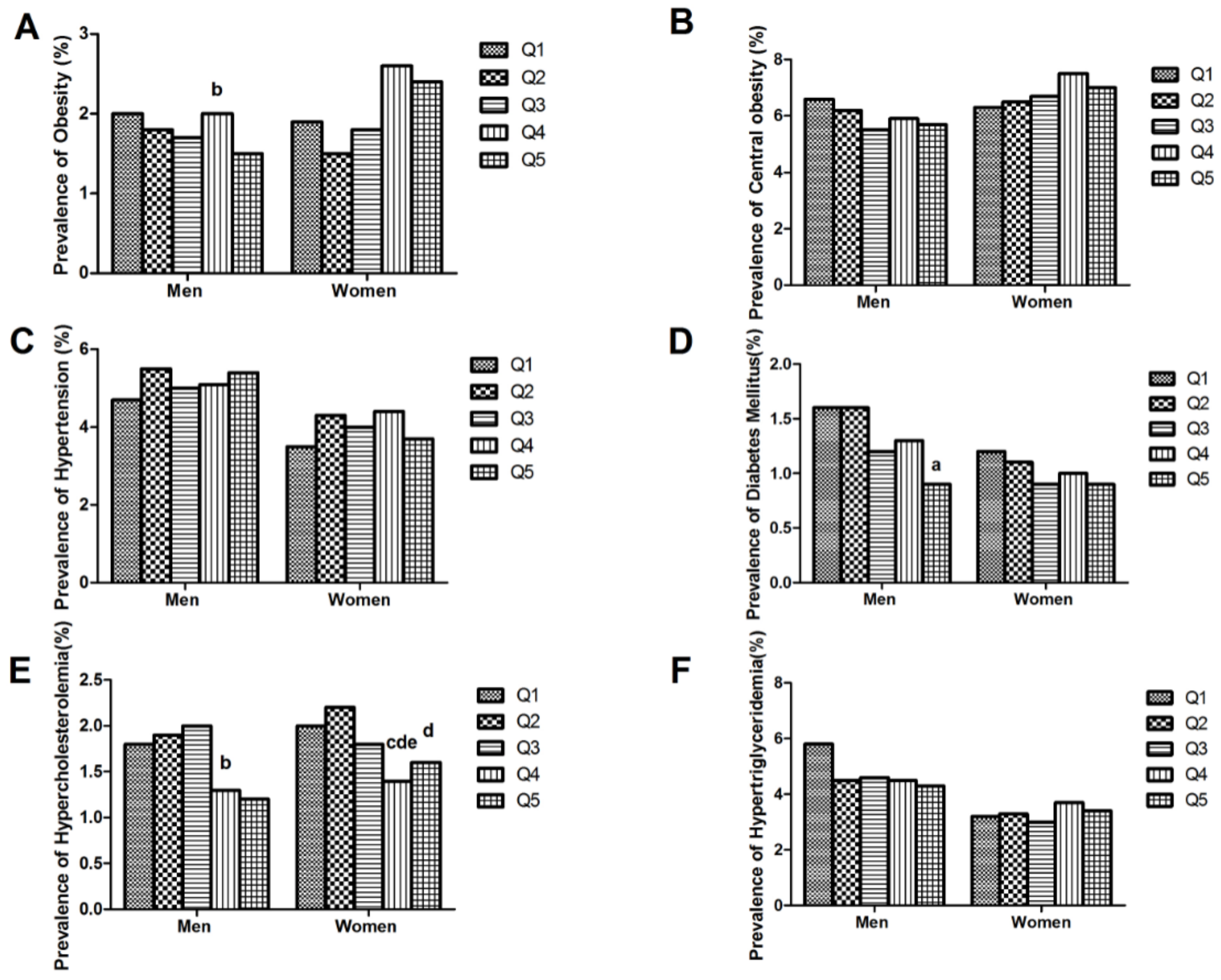

Figure 2. Prevalence of selected cardiovascular disease risk factors by gender, China 2009. (A) Prevalence of Obesity; (B) Prevalence of Central Obesity; (C) Prevalence of Hypertension; (D) Prevalence of Diabetes Mellitus; (E) Prevalence of Hypercholesterolemia; (F) Prevalence of Hypertriglyceridemia.
Note: a compared with Q1 in men; b compared with Q2 in men; c compared with Q1 in women; d compared with Q2 in women; e compared with Q3 in women

Table 2. Regression coefficients (95% CI) of CVD risk among Chinese men†

	Q1	Q2	Q3	Q4	Q5	*p*-trend‡
BMI§						
Model 1	0.00 (ref)	-0.07 (-0.43, 0.29)	-0.27 (-0.64, 0.09)	-0.34 (-0.70, 0.03)	-0.43 (-0.79, -0.06)*	0.007
Model 2	0.00 (ref)	0.02 (-0.34, 0.38)	-0.06 (-0.43, 0.30)	0.06 (-0.31, 0.43)	0.09 (-0.29, 0.48)	0.628
Model 3	0.00 (ref)	0.01 (-0.35, 0.37)	-0.09 (-0.46, 0.28)	0.01 (-0.38, 0.39)	0.02 (-0.39, 0.43)	0.962
WC						
Model 1	0.00 (ref)	-0.75 (-1.91, 0.41)	-1.68 (-2.84, -0.52)**	-1.45 (-02.61, -0.28)*	-1.71 (-2.87, -0.55)**	0.002
Model 2	0.00 (ref)	-0.36 (-1.51, 0.79)	-0.92 (-2.08, 0.24)	-0.04 (-1.23, 1.16)	0.11 (-1.12, 1.34)	0.802
Model 3	0.00 (ref)	-0.42 (-1.58, 0.74)	-1.05 (-2.23, 0.13)	-0.29 (-1.53, 0.94)	-0.24 (-1.57, 1.08)	0.699
SBP (mm Hg)						
Model 1	0.00 (ref)	1.69 (0.01, 3.37)*	0.58 (-1.09, 2.26)	0.46 (-1.22, 2.14)	0.90 (-0.77, 2.58)	0.647
Model 2	0.00 (ref)	1.78 (0.10, 3.47)*	0.82 (-0.89, 2.53)	0.73 (-1.02, 2.48	1.14 (-0.66, 2.95)	0.445
Model 3	0.00 (ref)	1.89 (0.19, 3.59)*	0.97 (-0.76, 2.71)	0.92 (-0.89, 2.73)	1.48 (-0.47, 3.42)	0.294
DBP (mm Hg)						
Model 1	0.00 (ref)	0.52 (-0.66, 1.70)	0.04 (-1.14, 1.21)	-0.40 (-1.58, 0.78)	0.57 (-0.60, 1.75)	0.782
Model 2	0.00 (ref)	0.60 (-0.58, 1.78)	0.35 (-0.84, 1.55)	0.02 (-1.20, 1.25)	1.11 (-0.16, 2.37)	0.224
Model 3	0.00 (ref)	0.49 (-0.71, 1.68)	0.17 (-1.05, 1.38)	-0.30 (-1.57, 0.97)	0.66 (-0.70, 2.02)	0.675
HbA1C (%)						
Model 1	0.00 (ref)	-0.02 (-0.12, 0.08)	-0.09 (-0.19, 0.01)	-0.05 (-0.15, 0.05)	-0.08 (-0.18, 0.02)	0.091
Model 2	0.00 (ref)	-0.01 (-0.11, 0.09)	-0.08 (-0.18, 0.02)	-0.03 (-0.13, 0.08)	-0.05 (-0.16, 0.06)	0.329
Model 3	0.00 (ref)	-0.01 (-0.11, 0.09)	-0.09 (-0.19, 0.02)	-0.04 (-0.14, 0.07)	-0.07 (-0.18, 0.05)	0.226
TC (mg/dL)						
Model 1	0.00 (ref)	-0.54 (-4.68, 3.60)	-3.57 (-7.71, 0.57)	-6.00 (-10.14, -1.86)**	-11.02 (-15.16, -6.89)***	0.000
Model 2	0.00 (ref)	0.52 (-3.60, 4.65)	-2.13 (-6.31, 2.05)	-2.25 (-6.52, 2.01)	-5.97 (-10.37, -1.57)**	0.005
Model 3	0.00 (ref)	1.22 (-2.91, 5.36)	-1.15 (-5.39, 3.09)	-0.72 (-5.13, 3.69)	-3.82 (-8.56, 0.92)	0.098
HDL-C (mg/dL)						
Model 1	0.00 (ref)	-0.44 (-2.75, 1.88)	0.82 (-1.50, 3.13)	1.18 (-1.13, 3.50)	0.32 (-1.99, 2.64)	0.426
Model 2	0.00 (ref)	-0.63 (-2.94, 1.68)	0.19 (-2.15, 2.53)	0.17 (-2.22, 2.57)	-1.51 (-3.98, 0.96)	0.421
Model 3	0.00 (ref)	-0.49 (-2.82, 1.83)	0.45 (-1.93, 2.83)	0.49 (-1.99, 2.97)	-0.87 (-3.53, 1.79)	0.802
LDL-C (mg/dL)						
Model 1	0.00 (ref)	4.42 (0.36, 8.47)*	1.89 (-2.17, 5.95)	-0.23 (-4.30, 3.83)	-3.81 (-7.87, 0.25)	0.015
Model 2	0.00 (ref)	4.97 (0.91, 9.03)*	2.79 (-1.32, 6.91)	2.20 (-2.00, 6.40)	-0.13 (-4.47, 4.20)	0.701
Model 3	0.00 (ref)	5.16 (1.08, 9.24)*	2.95 (-1.22, 7.13)	2.42 (-1.93, 6.77)	0.08 (-4.59, 4.76)	0.832
TG (mg/dL)						
Model 1	0.00 (ref)	-24.71 (-42.12, -7.31)**	-31.05 (-48.47, -13.63)***	-27.99 (-45.41, -10.57)**	-37.50 (-54.91, -20.09)***	0.000
Model 2	0.00 (ref)	-20.16 (-37.56, -2.76)*	-24.26 (-41.90, -6.63)**	-14.58 (-32.58, 3.41)	-18.27 (-36.84, 0.31)	0.096
Model 3	0.00 (ref)	-18.42 (-35.91, -0.92)*	-21.50 (-39.40, -3.61)*	-9.75 (-28.38, 8.88)	-11.68 (-31.71, 8.35)	0.375

BMI: body mass index; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1C: hemoglobin A1c; TC: total cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglycerides; Q: quintiles; ref: reference group.
†All of the models were constructed using three-level mixed-effects linear regression with maximum likelihood estimation methods. ‡*p*-trend was calculated across the quintiles of each carbohydrate intake (% energy) among participants, and this variable was entered as a continuous term in the regression models. §Model 1 adjusted for age only; model 2 additionally adjusted for individual income, education level, urbanicity index, physical activity, smoking status, alcohol consumption; model 3 further adjusted for dietary intake including total energy, grains and cereals, vegetables and fruits. $^{*}p<0.050$, $^{**}p<0.010$, $^{***}p<0.001$.

Table 3. Regression coefficients (95% CI) of CVD risk among Chinese women†

	Q1	Q2	Q3	Q4	Q5	*p*-trend‡
BMI						
Model 1§	0.00 (ref)	-0.08 (-0.42, 0.26)	0.03 (-0.31, 0.37)	0.43 (0.09, 0.77)*	0.37 (0.03, 0.71)*	0.002
Model 2	0.00 (ref)	-0.07 (-0.41, 0.28)	-0.01 (-0.36, 0.34)	0.44 (0.09, 0.80)*	0.33 (-0.04, 0.71)	0.011
Model 3	0.00 (ref)	-0.08 (-0.42, 0.27)	-0.03 (-0.38, 0.32)	0.40 (0.04, 0.77)*	0.27 (-0.13, 0.66)	0.046
WC						
Model 1	0.00 (ref)	0.02 (-1.03, 1.07)	-0.14 (-1.19, 0.92)	1.43 (0.38, 2.49)**	1.26 (0.20, 2.31)*	0.002
Model 2	0.00 (ref)	-0.03 (-1.10, 1.03)	-0.28 (-1.35, 0.80)	1.34 (0.23, 2.44)*	0.97 (-0.17, 2.12)	0.021
Model 3	0.00 (ref)	-0.02 (-1.09, 1.04)	-0.23 (-1.32, 0.85)	1.35 (0.21, 2.48)*	1.00 (-0.23, 2.22)	0.031
SBP(mm Hg)						
Model 1	0.00 (ref)	1.46 (-0.29, 3.21)	2.41 (0.66, 4.16)**	2.56 (0.81, 4.32)**	2.17 (0.42, 3.92)*	0.006
Model 2	0.00 (ref)	1.36 (-0.42, 3.13)	1.95 (0.16, 3.75)*	2.01 (0.17, 3.85)*	1.48 (-0.43, 3.39)	0.092
Model 3	0.00 (ref)	1.38 (-0.40, 3.15)	2.13 (0.32, 3.94)*	2.13 (0.24, 4.01)*	1.72 (-0.33, 3.76)	0.062
DBP (mm Hg)						
Model 1	0.00 (ref)	0.86 (-0.25, 1.97)	1.33 (0.22, 2.45)*	1.59 (0.48, 2.71)**	1.64 (0.53, 2.75)**	0.001
Model 2	0.00 (ref)	0.71 (-0.42, 1.84)	1.14 (-0.00, 2.29)	1.45 (0.27, 2.62)*	1.49 (0.27, 2.70)*	0.008
Model 3	0.00 (ref)	0.70 (-0.43, 1.84)	1.20 (0.04, 2.36)*	1.48 (0.28, 2.69)*	1.56 (0.26, 2.86)*	0.009
HbA1C (%)						
Model 1	0.00 (ref)	0.04 (-0.05, 0.13)	0.02 (-0.07, 0.11)	0.10 (0.01, 0.19)*	0.04 (-0.05, 0.13)	0.170
Model 2	0.00 (ref)	0.05 (-0.04, 0.14)	0.04 (-0.06, 0.13)	0.11 (0.02, 0.21)*	0.06 (-0.04, 0.16)	0.117
Model 3	0.00 (ref)	0.05 (-0.04, 0.145)	0.04 (-0.05, 0.14)	0.113 (0.02, 0.21)*	0.07 (-0.04, 0.17)	0.112
TC (mg/dL)						
Model 1	0.00 (ref)	2.79 (-1.06, 6.65)	-1.16 (-5.01, 2.70)	-4.05 (-7.91, -0.19)*	-5.29 (-9.14, -1.43)**	0.000
Model 2	0.00 (ref)	3.43 (-0.48, 7.35)	-0.25 (-4.20, 3.70)	-2.03 (-6.09, 2.03)	-2.77 (-6.98, 1.45)	0.035
Model 3	0.00 (ref)	3.62 (-0.30, 7.54)	0.27 (-3.73, 4.26)	-1.39 (-5.55, 2.77)	-1.61 (-6.12, 2.90)	0.168
HDL-C(mg/dL)						
Model 1	0.00 (ref)	1.42 (-0.45, 3.29)	-0.14 (-2.01, 1.73)	-1.56 (-3.43, 0.31)	-0.37 (-2.24, 1.50)	0.125
Model 2	0.00 (ref)	1.56 (-0.34, 3.47)	0.12 (-1.81, 2.04)	-1.26 (-3.24, 0.71)	0.00 (-2.05, 2.06)	0.324
Model 3	0.00 (ref)	1.67 (-0.24, 3.58)	0.35 (-1.60, 2.29)	-0.95 (-2.98, 1.07)	0.56 (-1.64, 2.75)	0.691
LDL-C(mg/dL)						
Model 1	0.00 (ref)	2.22 (-1.49, 5.94)	0.42 (-3.30, 4.13)	-2.76 (-6.48, 0.96)	-4.18 (-7.89, -0.46)*	0.003
Model 2	0.00 (ref)	2.74 (-1.04, 6.51)	1.19 (-2.62, 5.00)	-0.92 (-4.84, 2.99)	-1.87 (-5.94, 2.19)	0.150
Model 3	0.00 (ref)	2.90 (-0.88, 6.68)	1.64 (-2.21, 5.49)	-0.34 (-4.35, 3.67)	-0.83 (-5.18, 3.52)	0.431
TG (mg/dL)						
Model 1	0.00 (ref)	-0.75 (-12.23, 10.72)	-4.60 (-16.07, 6.88)	6.63 (-4.86, 18.11)	4.20 (-7.27, 15.68)	0.268
Model 2	0.00 (ref)	-0.08 (-11.76, 11.61)	-4.20 (-15.98, 7.59)	8.68 (-3.44, 20.80)	6.49 (-6.09, 19.06)	0.173
Model 3	0.00 (ref)	-0.05 (-11.74, 11.64)	-4.31 (-16.21, 7.60)	9.47 (-2.93, 21.88)	7.72 (-5.72, 21.17)	0.150

BMI: body mass index; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1C: hemoglobin A1c; TC: total cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglycerides; Q: quintiles; ref: reference group.

†All of the models were constructed using three-level mixed-effects linear regression with maximum likelihood estimation methods. ‡*p*-trend was calculated across the quintiles of each carbohydrate intake (% energy) among participants, and this variable was entered as a continuous term in the regression models. §Model 1 adjusted for age only; model 2 additionally adjusted for individual income, education level, urbanicity index, physical activity, smoking status, alcohol consumption; model 3 further adjusted for dietary intake including total energy, grains and cereals, vegetables and fruits. $^{*}p<0.050$, $^{**}p<0.010$, $^{***}p<0.001$.

consumption. In women, the highest intakes of carbohydrates (>68.8% of energy) were related to higher BMI, WC, and SBP after adjusting for age only. A significant positive association of carbohydrate intake with DBP of 1.56 (95% CI: 0.26-2.86) was observed after adjusting for all confounders. However, the top quintile of carbohydrate intake in women subjects was negative correlated with TC and LDL-C compared with those in the other lower carbohydrate intake quintiles after adjusting for age only. However, HbA1C and HDL-C were not significantly related to carbohydrate intake in either men or women compared with the reference group.

The ORs and 95% CIs for CVD risk factors according to the five levels of carbohydrate intake for men and women are shown in Tables 4 and 5. After adjustment for education level, age, physical activity, alcohol consumption, urbanicity index, income, and smoking status, men with higher carbohydrate intake (3rd, 4th and 5th quintiles) were approximately 24-38% less likely to have high TC than those in the reference group. When dietary intake and BMI were additionally adjusted, the relationship of impaired HbA1C with carbohydrate intake was strengthened in men. Comparing all quintiles of carbohydrate intake, the ORs (95% CI) of impaired glucose tolerance were 1.43 (0.85-2.40), 1.19 (0.71-1.97), 1.87 (1.01-3.44) and 2.08 (1.04-4.16) (p for trend=0.034) for the 2nd, 3rd, 4th, and 5th quintiles, respectively. Men who consumed the most carbohydrates (>57.9% of energy) (4th and 5th quintiles) were approximately 1.87-2.08 times more likely to have impaired HbA1C than those in the reference group. The ORs for general obesity, central obesity, hypertension, high TG, low HDL-C and high LDL-C did not differ significantly among the five quintiles in men (Table 4).

However, in women, the OR for high TC was 0.75 (95% CI: 0.57-0.98) for the highest carbohydrate intake (>68.8% of energy) compared with the reference group after adjustment for age only. After additional adjustments for some potentially confounding variables, women with higher carbohydrate intake (58.3-61.8% of energy) (4th quintile) were approximately 3.95 times more likely to have general obesity than those in the reference group. We found that the risk of high LDL-C was inversely associated with the highest quintiles of carbohydrate intake (OR: 0.73; 95% CI: 0.53-0.99) compared with the reference group. The ORs for central obesity, hypertension, diabetes mellitus, high TG and low HDL-C did not differ significantly among the quintiles in women (Table 5).

DISCUSSION

Despite the rapid economic development and transitions in the dietary patterns of the population in China, carbohydrate intake remains the major source of energy intake. This study is the first to examine the associations between risk factors for CVD and carbohydrate intake among Chinese adults aged 18-60. The results of this population-based study showed that high carbohydrate intake might associate with the risk of CVD in the Chinese population.

In our study, excessive intake of carbohydrates (>68.8% of energy) was associated with high blood pressure, WC and BMI in women but not in men. Similar results have been reported for the Korean population.[13] Results from a meta-analysis demonstrated that low-carbohydrate diets were effective at reducing body weight, BMI, WC, TG, and blood pressure.[23] Previous studies have reported that weight was reduced by low-carbohydrate diets.[24] Mean body weight loss ranged from 2.1 to 14.9 kg for low-carbohydrate diets in randomized controlled trials.[25-27] Newby reported that those with the highest carbohydrate consumption (61.9% of energy) had the lowest annual gain in BMI and WC.[28] Cheung[29] demonstrated that obesity and insulin resistance were not caused by excessive dietary fat intake, but by carbohydrate intake that exceeds energy needs. Another established risk factor for CVD is hypertension. Lower blood pressures are associated with a decreased risk of coronary events, stroke and heart failure.[30] Low-carbohydrate diets decreased SBP (4.81 mm Hg) and DBP (3.1 mm Hg) in recent randomized controlled trials.[23] Weight loss may decrease blood pressure.[31]

Previous studies have reported that high carbohydrate intake, especially refined carbohydrates, increases the risk of Type 2 diabetes mellitus.[32,33] One study found that the risk for myocardial infarction was increased by diabetes mellitus.[34] Elevated glycated hemoglobin has been associated with a high risk of coronary heart disease.[35] A low-carbohydrate dietary slightly decreases plasma glucose and glycated hemoglobin.[23] Moreover, fasting levels of blood glucose and HbA1C have been shown to decrease in association with low-carbohydrate intake diets in most randomized controlled trials.[36-37] In our study, carbohydrate intakes were positively related to impaired glucose tolerance only in Chinese men. High-carbohydrate, low-fat diets also increase insulin concentrations, which have been reported to increase risk of CVD. It is speculated that insulin-resistance is associated with the untoward effects on glucose, insulin and lipoprotein metabolism when the individual consumes a high carbohydrate, low-fat diet.[12]

Epidemiological studies have shown that elevated concentrations of serum TC and LDL-C are independent risk factors for CVD.[12] Our study showed that the high TC level was inversely associated with high intake of carbohydrates (>68.2% and >68.8% of energy in men and women, respectively). Similar result has been reported that an inverse relationship between serum TC and carbohydrate intake (% of energy) from national survey on nutrition and health status of the Chinese people 2002. High TC were decreased 18% and 31% in subjects with 55%-65% and >65% carbohydrate intake, respectively, compared to those with <55% carbohydrate intake.[38] Moreover, increased levels of LDL-C clearly increase the risks for CVD.[39,40] Our study showed an inverse association between LDL-C and carbohydrate intake (% of energy) in Chinese women, which was consistent with the study that demonstrated increased carbohydrate intake was associated with lower LDL-C.[41] It has been shown that increasing carbohydrate intake may affect lipoprotein concentrations and glucose metabolism.[13] Turley found that TC and LDL-C fell from 5.52 (1.04) mmol/L and 3.64 (0.88) mmol/L, respectively on the Western diet (36%, 18% and 43% energy from total, saturated, and carbohydrate, respectively) to 4.76 (1.10) mmol/L and 2.97(0.94) mmol/L on the high-carbohydrate diet (22%,

Table 4. ORs (95% CI) of CVD risk among Chinese men†

	Q1	Q2	Q3	Q4	Q5	*p*-trend‡
General Obesity						
Model 1§	1.00 (Ref)	0.90 (0.61, 1.33)	0.82 (0.55, 1.24)	1.01 (0.68, 1.51)	0.75 (0.49, 1.16)	0.589
Model 2	1.00 (Ref)	0.93 (0.62, 1.38)	0.93 (0.61, 1.40)	1.18 (0.78, 1.78)	0.94 (0.60, 1.48)	0.842
Model 3	1.00 (Ref)	0.93 (0.62, 1.39)	0.92 (0.60, 1.41)	1.16 (0.76, 1.79)	0.93 (0.57, 1.52)	0.910
Central Obesity						
Model 1	1.00 (Ref)	0.91 (0.71, 1.19)	0.75 (0.58, 0.99)*	0.85 (0.65, 1.19)	0.79 (0.59, 1.04)	0.077
Model 2	1.00 (Ref)	0.94 (0.73, 1.23)	0.80 (0.61, 1.06)	0.97 (0.73, 1.28)	0.90 (0.67, 1.22)	0.533
Model 3	1.00 (Ref)	0.96 (0.72, 1.26)	0.81 (0.57, 1.16)	0.99 (0.73, 1.34)	0.93 (0.66, 1.31)	0.680
Hypertension						
Model 1	1.00 (Ref)	1.38 (0.90, 2.12)	1.08 (0.75, 1.56)	1.15 (0.78, 1.68)	1.27 (0.84, 1.93)	0.476
Model 2	1.00 (Ref)	1.45 (0.87, 2.44)	1.13 (0.73, 1.73)	1.21 (0.76, 1.90)	1.30 (0.79, 2.13)	0.486
Model 3	1.00 (Ref)	1.95 (0.77, 4.93)	1.60 (0.65, 3.90)	2.29 (0.78, 6.73)	1.39 (0.50, 3.89)	0.614
Model 4	1.00 (Ref)	1.32 (0.99, 1.76)	1.13 (0.83, 1.53)	1.15 (0.83, 1.58)	1.24 (0.88, 1.75)	0.431
Impaired HbA1C						
Model 1	1.00 (Ref)	1.42 (0.79, 2.54)	1.05 (0.62, 1.78)	1.72 (0.91, 3.26)	1.86 (0.93, 3.72)	0.069
Model 2	1.00 (Ref)	1.45 (0.87, 2.44)	1.13 (0.73, 1.73)	1.21 (0.76, 1.90)	1.30 (0.79, 2.14)	0.064
Model 3	1.00 (Ref)	1.52 (0.83, 2.78)	1.20 (0.67, 2.14)	2.00 (1.00, 2.98)*	2.21 (1.03, 4.72)*	0.037
Model 4	1.00 (Ref)	1.43 (0.85, 2.40)	1.19 (0.71, 1.97)	1.87 (1.01, 3.44)*	2.08 (1.04, 4.16)*	0.034
High HbA1C						
Model 1	1.00 (Ref)	0.79 (0.28, 2.25)	0.58 (0.19, 1.77)	0.62 (0.19, 2.00)	0.67 (0.23, 1.97)	0.080
Model 2	1.00 (Ref)	1.45 (0.87, 2.44)	1.13 (0.77, 1.73)	1.35 (0.87, 2.08)	1.28 (0.38, 1.98)	0.205
Model 3	1.00 (Ref)	1.39 (0.49, 3.89)	0.56 (0.18, 1.74)	1.07 (0.34, 3.37)	0.43 (0.12, 1.62)	0.239
Model 4	1.00 (Ref)	1.47 (0.53, 4.08)	0.62 (0.22, 1.76)	1.13 (0.37, 3.48)	0.50 (0.14, 1.75)	0.255
High TG						
Model 1	1.00 (Ref)	0.86 (0.65, 1.14)	0.76 (0.52, 1.11)	0.78 (0.54, 1.12)	0.72 (0.47, 1.11)	0.830
Model 2	1.00 (Ref)	0.88 (0.56, 1.37)	0.76 (0.40, 1.43)	0.88 (0.55, 1.40)	0.87 (0.54, 1.41)	0.600
Model 3	1.00 (Ref)	0.92 (0.61, 1.37)	0.81 (0.46, 1.45)	0.95 (0.63, 1.41)	0.95 (0.63, 1.45)	0.824
High LDL-C						
Model 1	1.00 (Ref)	1.27 (0.98, 1.65)	0.93 (0.71, 1.22)	0.88 (0.67, 1.16)	0.76 (0.57, 1.01)	0.008
Model 2	1.00 (Ref)	1.35 (1.04, 1.76)	1.02 (0.77, 1.34)	1.02 (0.76, 1.35)	0.91 (0.68, 1.24)	0.259
Model 3	1.00 (Ref)	1.46 (1.12, 1.91)**	1.13 (0.85, 1.50)	1.18 (0.87, 1.59)	1.13 (0.81, 1.58)	0.824
Low HDL-C						
Model 1	1.00 (Ref)	0.74 (0.32, 1.68)	0.68 (0.26, 1.78)	0.70 (0.26, 1.93)	0.94 (0.53, 1.68)	0.721
Model 2	1.00 (Ref)	0.76 (0.37, 1.57)	0.75 (0.38, 1.48)	0.76 (0.35, 1.65)	1.14 (0.61, 2.14)	0.855
Model 3	1.00 (Ref)	0.75 (0.35, 1.66)	0.76 (0.38, 1.55)	0.79 (0.36, 1.74)	1.30 (0.57, 2.97)	0.618
High TC						
Model 1	1.00 (Ref)	0.98 (0.76, 1.26)	0.71 (0.54, 0.91)**	0.71 (0.54, 0.92)*	0.52 (0.39, 0.69)***	<0.001
Model 2	1.00 (Ref)	1.05 (0.81, 1.35)	0.76 (0.59, 0.99)*	0.84 (0.64, 1.10)*	0.62 (0.46, 0.84)**	0.001
Model 3	1.00 (Ref)	1.13 (0.88, 1.47)	0.85 (0.64, 1.12)	0.97 (0.72, 1.30)	0.77 (0.55, 1.07)	0.083

HbA1C: hemoglobin A1c; TG: triglycerides; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol; TC: total cholesterol; Q: quintiles; ref: reference group.
†All of the models were constructed using mixed-effects linear regression with maximum likelihood estimation methods. ‡*p*-trend was calculated across the quintiles of each carbohydrate intake (% energy) among participants, and this variable was entered as a continuous term in the regression models. §Model 1 adjusted for age only; model 2 additionally adjusted for individual income, education level, urbanicity index, physical activity, smoking status, alcohol consumption; model 3 further adjusted for dietary intake including total energy, grains and cereals, vegetables and fruits; model 4 further adjusted for BMI. *$p<0.050$, **$p<0.010$, ***$p<0.001$.

Table 5. ORs (95% CI) of CVD risk among Chinese women†

	Q1	Q2	Q3	Q4	Q5	*p*-trend‡
General Obesity						
Model 1§	1.00 (Ref)	0.69 (0.30, 1.56)	0.84 (0.38, 1.83)	2.84 (1.16, 6.99)*	2.09 (0.92,4.76)	0.010
Model 2	1.00 (Ref)	0.70 (0.29, 1.69)	0.79 (0.33, 1.86)	4.01 (1.42, 11.32)**	2.43 (0.94,6.30)	0.010
Model 3	1.00 (Ref)	0.71 (0.29, 1.73)	0.79 (0.33, 1.91)	3.95 (1.38, 11.28)*	2.38 (0.87,6.53)	0.016
Central Obesity						
Model 1	1.00 (Ref)	0.96 (0.74, 1.24)	1.05 (0.81, 1.36)	1.21 (0.93, 1.57)	1.11 (0.85,1.46)	0.191
Model 2	1.00 (Ref)	0.95 (0.73, 1.24)	1.01 (0.77, 1.32)	1.22 (0.92, 1.60)	1.09 (0.82,1.45)	0.252
Model 3	1.00 (Ref)	0.96 (0.74, 1.26)	1.03 (0.78, 1.36)	1.24 (0.93, 1.65)	1.12 (0.82,1.54)	0.220
Hypertension						
Model 1	1.00 (Ref)	1.50 (0.79, 2.87)	1.42 (0.75, 2.68)	1.65 (0.83, 3.25)	1.23 (0.65,2.33)	0.498
Model 2	1.00 (Ref)	1.95 (0.76, 5.05)	1.50 (0.61, 3.68)	2.14 (0.76, 5.98)	1.21 (0.47,3.12)	0.746
Model 3	1.00 (Ref)	1.95 (0.77, 4.93)	1.60 (0.65, 3.90)	2.29 (0.78, 6.73)	1.39 (0.50,3.89)	0.508
Model 4	1.00 (Ref)	1.51 (0.58, 3.96)	1.32 (0.54, 3.26)	1.40 (0.55, 3.59)	1.10 (0.59,2.06)	0.838
Impaired HbA1C						
Model 1	1.00 (Ref)	1.00 (0.67, 1.49)	1.15 (0.77, 1.73)	1.35 (0.87, 2.08)	1.28 (0.38,1.98)	0.150
Model 2	1.00 (Ref)	1.09 (0.70, 1.58)	1.21 (0.79, 1.86)	1.40 (0.89, 2.22)	1.27 (0.80,2.00)	0.183
Model 3	1.00 (Ref)	1.02 (0.68, 1.55)	1.17 (0.76, 1.81)	1.33 (0.83, 2.11)	1.16 (0.71,1.19)	0.361
Model 4	1.00 (Ref)	1.07 (0.71, 1.61)	1.19 (0.78, 1.82)	1.28 (0.81, 2.00)	1.15 (0.71,1.86)	0.434
High HbA1C						
Model 1	1.00 (Ref)	0.79 (0.28, 2.25)	0.58 (0.19, 1.77)	0.62 (0.19, 2.00)	0.67 (0.23,1.97)	0.372
Model 2	1.00 (Ref)	1.03 (0.23, 4.54)	0.69 (0.18, 2.63)	0.87 (0.21, 3.58)	1.06 (0.19,5.89)	0.900
Model 3	1.00 (Ref)	1.06 (0.33, 3.45)	0.94 (0.28, 3.20)	1.31 (0.35, 4.88)	1.59 (0.31,8.06)	0.582
Model 4	1.00 (Ref)	1.59 (0.31, 8.23)	0.99 (0.20, 4.99)	1.11 (0.21, 5.94)	1.68 (0.22,12.81)	0.809
High TG						
Model 1	1.00 (Ref)	1.10 (0.80, 1.52)	1.05 (0.77, 1.44)	1.13 (0.81, 1.58)	1.03 (0.23,1.97)	0.842
Model 2	1.00 (Ref)	1.14 (0.79, 1.65)	1.09 (0.76, 1.55)	1.23 (0.82, 1.83)	1.08 (0.74,1.58)	0.640
Model 3	1.00 (Ref)	1.13 (0.78, 1.63)	1.06 (0.74, 1.52)	1.19 (0.79, 1.79)	1.03 (0.68,1.55)	0.836
High LDL-C						
Model 1	1.00 (Ref)	1.07 (0.83, 1.38)	0.95 (0.74, 1.23)	0.71 (0.54, 0.93)*	0.67 (0.51,0.88)**	<0.001
Model 2	1.00 (Ref)	1.09 (0.85, 1.41)	0.99 (0.76, 1.29)	0.75 (0.57, 0.98)*	0.71 (0.53,0.95)*	0.003
Model 3	1.00 (Ref)	1.10 (0.85, 1.42)	1.00 (0.77, 1.31)	0.76 (0.57, 1.01)	0.73 (0.53,0.99)*	0.011
Low HDL-C						
Model 1	1.00 (Ref)	0.93 (0.73, 1.18)	1.03 (0.82, 1.31)	1.09 (0.86, 1.39)	1.02 (0.80,1.30)	0.540
Model 2	1.00 (Ref)	0.91 (0.64, 1.31)	1.04 (0.75, 1.43)	1.17 (0.73, 1.88)	1.08 (0.74,1.56)	0.515
Model 3	1.00 (Ref)	0.91 (0.60, 1.38)	1.05 (0.74, 1.49)	1.19 (0.66, 2.15)	1.10 (0.71,1.70)	0.550
High TC						
Model 1	1.00 (Ref)	1.06 (0.83, 1.36)	0.98 (0.76, 1.26)	0.87 (0.67, 1.13)	0.75 (0.57,0.98)*	0. 016
Model 2	1.00 (Ref)	1.08 (0.83, 1.39)	1.01 (0.78, 1.31)	0.92 (0.70, 1.21)	0.80 (0.60,1.07)	0. 087
Model 3	1.00 (Ref)	1.09 (0.84, 1.41)	1.03 (0.79, 1.35)	0.96 (0.72, 1.27)	0.85 (0.62,1.17)	0. 261

HbA1C: hemoglobin A1c; TG: triglycerides; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol; TC: total cholesterol; Q: quintiles; ref: reference group.
†All of the models were constructed using mixed-effects linear regression with maximum likelihood estimation methods. ‡*p*-trend was calculated across the quintiles of each carbohydrate intake (% energy) among participants, and this variable was entered as a continuous term in the regression models. §Model 1 adjusted for age only; model 2 additionally adjusted for individual income, education level, urbanicity index, physical activity, smoking status, alcohol consumption; model 3 further adjusted for dietary intake including total energy, grains and cereals, vegetables and fruits; model 4 further adjusted for BMI. *$p<0.050$, **$p<0.010$, ***$p<0.001$.

6% and 59% energy from total, saturated, and carbohydrate, respectively).[42] Carbohydrate intakes were higher in China than in other Western countries. Chinese people consumed a low saturated fat with high carbohydrate from grains, vegetables, legumes, and fruit, which reduced TC and LDL-C for preventing dyslipidemia.[43] However, our study reported that HDL-C and TG were not associated with carbohydrate intake (% of energy) in either Chinese men or women.

However, an association between health outcomes and very-low-carbohydrate intake (<50% of energy) was lacking. Most importantly, a certain amount of carbohydrates is necessary to meet energy requirements. Therefore, moderate intake of carbohydrates (50-55% of energy) is more appropriate than either very-low- or very-high-carbohydrate intake,[44] consistent with the dietary reference intake (DRI) of carbohydrates (50% to 65% of energy) in China.[45]

There are many advantages of this study. The CHNS is a study with a wide age range and large size, after adjusting for a comprehensive range of potential confounders. This study is the first to examine the association between gender-specific consumption of carbohydrates and risk factors for CVD among Chinese men and women. Moreover, compared to self-reported food-frequency methods, the 24-h dietary recall administered by the reviewers provides a more precise assessment of carbohydrate intake. In addition, more precise and less biased estimates are obtained by the mixed-effect modeling method.

However, several limitations of this study should be considered. First, we used recalled dietary data, which might not reflect differences in carbohydrate intake by season because the data were collected between August and November. In addition, only carbohydrate intake (% of energy) was analyzed in the study, but the metabolic effects of carbohydrate consumption were reflected by the glycemic index.[46] It is necessary to assess the relationship between CVD risk factors and glycemic index in the Chinese population by using the CHNS. Furthermore, determining the long-term health effects of carbohydrate intake would be valuable for future research.

Conclusion

In our study, a high-carbohydrate diet was independently and strongly associated with increased risk of CVD (such as impaired glucose tolerance) in Chinese men aged 18-60. However, the highest quintile of carbohydrate intake (>68.2% and >68.8% of energy in men and women, respectively) was inversely related to high TC in all adults and high LDL-C in women. Future studies should examine the mechanisms underlying the associations between risk factors for CVD and different types and sources of dietary carbohydrates.

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AUTHORG DISCLOSURES

No potential conflict of interest was declared by the authors.

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