Original Article

Association between High Fat-low Carbohydrate Diet Score and Newly Diagnosed Type 2 Diabetes in Chinese Population*

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Abstract

Objective To study the association between high fat-low carbohydrate diet score and newly diagnosed type 2 diabetes in Chinese population.

Methods Data about 20 717 subjects aged 45-59 years from the cross-sectional 2002 China National Nutrition and Health Survey were analyzed. High fat-low carbohydrate diet was scored according to the energy of carbohydrate, fat, and protein.

Results Of the 20 717 subjects, 1 332 were diagnosed with hyperglycemia and 662 were newly diagnosed with type 2 diabetes. Multivariate adjusted analysis showed that the highest score of type 2 diabetes patients was 2.75 (95% CI: 2.09-3.61). The score of type 2 diabetes patients was 1.87 (95% CI: 1.35-2.58) after further adjustment for their socioeconomic status and physical activity. No significant difference was found in the odds ratio after further adjustment for BMI, blood pressure, lipid level, and energy intake. No evidence was observed for the relation between high fat-low carbohydrate-diet score in type 2 diabetes patients due to high family income, less education, physical activity, overweight, hypertension, high TG, or low HDL level.

Conclusion High fat-low carbohydrate diets, far different from traditional Chinese diets, are associated with the high incidence of type 2 diabetes in Chinese population.

Key words: Diabetes; Fat; Carbohydrate; Diet score; Chinese population

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INTRODUCTION

Theoretically, the traditional Chinese diet, characterized by a high intake of plant foods, high carbohydrate and very low dietary fat, has a potential to protect the heart. However, with the economic transition, this potential is switching rapidly towards a Western-style. Dietary fat provides only 11%-22% energy for the people in the 1980s during which no significant correlation was found between dietary fat intake and body weight[1-2]. The average energy intake from fat increased from 21.8% in 1991 to 22.2% in 1993, from 25.8% in 1997 to 28.9% and 29.6% in 2000 and 2002. Meanwhile, the proportion of total dietary energy intake from carbohydrate decreased from 65.6% in 1991 to 65.0% in 1993, from 61.9% in 1997 to 58.8% and 58.6% in 2000 and 2002[3-4], while the prevalence of type 2 diabetes and

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its related factors including obesity, hypertension and dyslipidemia has dramatically increased. The most recent data indicate that the prevalence of diabetes in Chinese adults has reached 9.7% with another 15.5% diagnosed with either impaired fasting glucose or glucose tolerance[5].

Whether the nutrition transition from high carbohydrate-low fat diet to the opposite increases the trend of diabetes and its related factors is still unknown, because elevated dietary fat increases with the increasing sedentary lifestyle and the reducing infectious diseases, which may also lead to chronic disease risks. A modest but significant independent effect of energy from fat on BMI has been found in Chinese adults[6]. However, information about the role of a high fat-low carbohydrate diet in diabetes is so far limited in China.

The present study is to investigate the association between high fat-low carbohydrate diet and newly diagnosed type 2 diabetes in China according to the cross-sectional data from 2002 China National Nutrition and Health Survey (CNNHS).

SUBJECTS AND METHODS

Study Population

The 2002 CNNHS was a national representative cross-sectional study on nutrition and chronic diseases. A stratified multistage probability cluster sampling design was used in this survey[4,7]. The county was divided into 6 strata according to its socioeconomic characteristics. In the first stage of sampling, 22 counties were randomly selected from each of the 6 strata. In the second stage, 3 townships were randomly selected from each of the selected counties. Two residential villages were randomly selected from each township and 90 households were randomly sampled from each village for physical examination. A total of 795 residential committees or villages and 68 828 families were sampled. About one-third of the 90 households were randomly selected to participate in the dietary survey and blood was drawn for the measurement of fasting blood glucose and lipid levels. The response rate was 87%[7]. Oral glucose tolerance (OGT) was tested in subjects with their fasting glucose level $\geqslant$5.5 mmol/L.

The diet and blood glucose data about 21 390 subjects aged 45-59 years and 673 subjects with diagnosed diabetes were excluded in this study. The final number of subjects in this study was 20 717. The survey protocol was approved by the Ethical Committee of the National Institute for Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. All subjects signed their consent form.

Dietary Assessment

Trained interviewers interviewed with the subjects at their home about their food intake in the last 24 h, once a day for 3 consecutive days using the dietary recall method. The interviewers weighed the cooking oil and condiment consumed by all family members during the 3 days. The percentage of oil and condiments the subjects consumed was calculated as the ratio of his/her energy intake divided by the energy intake of all family members. The energy and nutrient intake were calculated according to the data listed on the China Food Composition Table[8].

Calculation of the High Fat-low Carbohydrate Diet Score

The high fat-low carbohydrate diet score, also known as “low-carbohydratediet score” was calculated with the method developed by Halton et al.[9]. Since the diet of Chinese subjects with the highest score did not include a very low carbohydrate as compared to the general low carbohydrate diet[10], but included a relatively high fat intake, the score was termed as “high fat-low carbohydrate diet score”.

The subjects included in this study were divided into 11 strata as described by Halton et al.[9]. Fat and protein intake was scored as 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, and 0 respectively while the carbohydrate intake was scored as 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 respectively in men and women (Table 1). The scores of fat, protein and carbohydrate intake were summed to express the overall high fat-low carbohydrate diet score (range 0-3). The animal and plant high fat-low carbohydrate scores were recorded as described by Halton et al. [9].

Outcome Assessment

Blood was drawn from the subjects 10-14 h after fasted. Plasma glucose level in fasting blood sample was measured with a spectrophotometer within 4 h. Oral glucose tolerance was tested in subjects with their fasting plasma glucose level $\geqslant$5.5 mmol/L. WHO Expert Committee-recommended criteria for diabetes mellitus were used in diagnosis of diabetes[11]. Hyperglycaemia was defined as fasting plasma glucose (FPG) level $\geqslant$6.1 mmol/L and/or 2-h plasma glucose level $\geqslant$7.8 mmol/L. Type 2 diabetes was defined as FPG $\geqslant$7 mmol/L and/or 2-h plasma glucose $\geqslant$11.1 mmol/L. Subjects with type 2 diabetes were excluded from this study[11].

Measurement of Non-dietary Factors

Information about current smoking and drinking was collected by face to face interview with the subjects. Current smoking was identified as having smoked at least one piece a week in the past 30 days, and alcohol drinking was identified as having drunk alcohol at least once a week. Sedentary activity was investigated with one-year physical activity questionnaire. Physical activity was recorded as a 3-level variable (light, moderate, and heavy) recommended by the China Nutrition Society[12], to reflect the total energy expenditure.

Fasting body weight was measured in the morning to the nearest 0.10 kg with a balance-beam scale while the subjects wore a light weight clothing. Body height of bare footed subjects was measured to the nearest 0.1 cm with a standard steel strip stadiometer. BMI (kg/m^2) was calculated according to the fasting body weight and height. Obesity was defined when the BMI was $\geqslant 28\ kg/m^2$[13].

Plasma total cholesterol (TC), triglyceride (TG), and HDL-C levels were measured with a Hitachi 7060 or 7180 auto-analyzer (Hitachi, Tokyo, Japan). LDL level was expressed as TC minus TG and HDL-C. High TG level was defined as it was $\geqslant 1.7$ mmol/L, Low HDL-C level as it was <1.03 mmol/L in males and <1.29 mmol/L in females[14] and high LDL level as it was $\geqslant$ 3.62 mmol/L[15].

Resting blood pressure of the subjects was measured twice with its mean value recorded. Hypertension was defined as systolic blood pressure (BP) $\geqslant 130$ mmHg and/or diastolic BP $\geqslant 85$ mmHg[14].

Statistical Method

The subjects were divided into quintiles of the high fat-low carbohydrate diet score. The odds ratio of hyperglycemia and type 2 diabetes calculated in a specific quintile was compared with that calculated in the lowest quintile. Sex, family history of diabetes, educational level, current smoking, alcohol use, sedentary activity time and physical activity level, BMI, SBP, TG, LDL, and HDL were included in the multivariate models. The subjects were classified by stratified analysis according to their sex, overweight, family income, educational level, sedentary activity time, and physical activity level. Interaction between the high fat-low carbohydrate diet score and stratified variables was tested by adding a multiplicative factor in the logistic regression model.

RESULTS

The average high fat-low carbohydrate diet score was 5-25 in the highest quintile. The mean energy of fat and carbohydrate was 16.7% and 72.5% respectively in the lowest quintile, and was 42.2% and 42.9% respectively in the highest quintile (Table 1).

Food and Nutrient Intake in Different High Fat-low Carbohydrate Diet Score

The subjects with a higher high fat-low carbohydrate diet score tended to consume less grain food and more red meat with a lower cereal fiber and dietary glycemic load, and a higher dietary fat including unsaturated fat (Table2).

Characteristics in Different High Fat-low Carbohydrate Diet Score

The subjects with a higher high fat-low carbohydrate diet score drank more alcohol and smoked less and had a higher family income and educational level with a lower day time physical activity level, a longer leisure time and a sedentary activity time (Table 3). The high fat-low carbohydrate diet score was positively associated with the BMI, plasma TG and LDL level and negatively associated with the blood pressure and HDL level in the subjects after adjustment for their age, sex and socioeconomic status (Table 3). Further analysis showed that the LDL increased 1.19-fold with the increasing quintile of the high fat-low carbohydrate diet score (95% CI: 1.68-2.95, $P<0.001$). The TG and HDL levels were significantly lower (odds ratio: 0.96, 95% CI: 0.93-0.99, $P=0.011$; odds ratio: 0.88, 95%CI: 0.86-0.91, $P<0.001$). However, they were not significantly associated with obesity or hypertension in the subjects after adjustment for their socioeconomic variables.

Association between Newly Diagnosed Hyperglycaemia and Type 2 Diabetes with High Fat-low Carbohydrate Diet Score

Of the 20 717 subjects, 1 332 were diagnosed with hyperglycaemia and 662 with type 2 diabetes. Sex- and age-adjusted analysis showed that the incidence of type 2 diabetes in the subjects with a highest quintile of the high fat-low carbohydrate diet score was 2.75 (95% CI: 2.09-3.61) and decreased to 1.87 (95% CI: 1.35-2.58) after further adjustment for socioeconomic status and physical activity. No significant difference was found in the odds ratio after further adjustment for their BMI, blood pressure and lipid level or after further adjustment for their total calories and lipid controls by diet or drags (odds ratio: 1.88, 95% CI: 1.34-2.64).

Table 1. Criteria for Determining High Fat-low Carbohydrate Diet Score

Points	Carbohydrate Intake	Total Protein Intake	Total Fat Intake	Animal-protein Intake	Animal-fat Intake	Vegetable-protein Intake	Vegetable-fat Intake
Men				**percentage of energy**			
0	>73.5	<8.7	<15.1	0	<0.4	<5.8	<3.9
1	69.5-73.5	8.7-9.5	15.1-18.8	0.1-0.5	0.4-2.2	5.8-6.5	3.9-8.0
2	66.3-69.4	9.6-10.1	18.9-22.0	0.6-1.1	2.3-4.4	6.6-7.1	8.1-11.1
3	63.3-66.2	10.2-10.6	22.1-25.0	1.2-1.7	4.5-6.6	7.2-7.6	11.2-13.7
4	60.2-63.2	10.7-11.2	25.1-27.7	1.8-2.3	6.7-8.7	7.7-8.1	13.8-16.0
5	57.2-60.1	11.3-11.7	27.8-30.4	2.4-3.0	8.8-10.9	8.2-8.6	16.1-18.4
6	54.2-57.1	11.8-12.4	30.5-33.3	3.1-3.7	11.0-13.4	8.7-9.1	18.5-21.0
7	50.8-54.1	12.5-13.0	33.4-36.7	3.8-4.6	13.5-16.2	9.2-9.7	21.1-23.9
8	46.7-50.7	13.1-14.1	36.8-40.7	4.7-5.8	16.3-20.0	9.8-10.5	24.0-27.6
9	40.9-46.6	14.2-15.9	40.8-46.4	5.9-7.5	20.1-25.6	10.6-11.4	27.7-33.4
10	<40.9	>15.9	>46.4	>7.5	>25.6	>11.4	>33.4
Women				**percentage of energy**			
0	>73.3	<8.8	<15.1	0	0	<6.0	<4.3
1	69.2-73.3	8.8-9.6	15.1-19.0	0.1-0.4	0.1-2.1	6.0-6.7	4.3-8.5
2	65.8-69.1	9.7-10.3	19.1-22.4	0.5-1.0	2.2-4.2	6.8-7.3	8.6-11.7
3	62.6-65.7	10.4-10.8	22.5-25.3	1.1-1.7	4.3-6.3	7.4-7.8	11.8-14.3
4	59.6-62.5	10.9-11.4	25.4-28.1	1.8-2.3	6.4-8.4	7.9-8.2	14.4-16.6
5	56.4-59.5	11.5-11.9	28.2-30.9	2.4-3.0	8.5-10.6	8.3-8.7	16.7-19.0
6	53.3-56.3	12.0-12.5	31.0-34.1	3.1-3.8	10.7-13.2	8.8-9.3	19.1-21.6
7	49.9-53.2	12.6-13.3	34.2-37.4	3.9-4.7	13.3-15.9	9.4-9.9	21.7-24.6
8	45.7-49.8	13.4-14.3	37.5-41.4	4.8-5.8	16.0-19.8	10.0-10.6	24.7-28.4
9	39.9-45.6	14.4-16.1	41.5-47.1	5.9-7.6	19.9-25.5	10.7-11.6	28.5-34.6
10	<39.9	>16.1	47.1	>7.6	>25.5	>11.6	>34.6

Type 2 diabetes was significantly associated with the high fat-low carbohydrate diet score. Animal fat and protein in the subjects were observed in the sex- and age-adjusted analysis but not in the multivariate model after further adjustment for their socioeconomic status and physical activity level, even after adjustment for the potential confounders (Table 4).

The stratified analysis showed no evidence for the relation between high fat-low carbohydrate diet score, high family income, less education, physical inactivity, overweight, hypertension, high TG level, or low HDL level in the subjects (Table 5). The incidence of type 2 diabetes increased with the increasing high fat-low carbohydrate diet score of the subjects who were sedentary and overweight with a low HDL level.

DISCUSSION

This cross-sectional survey showed that the high fat-low carbohydrate diet score was associated with type 2 diabetes mellitus in the subjects, which was remarkably lower after adjustment for their socioeconomic status and physical activity.

Theoretically, high fat diet can potentially increase the risk of type 2 diabetes because it reduces the expression of glucose sensing gene, glucose transporter 2 (GLUT2), glucokinase (GK), and impairs insulin secretion[16]. Furthermore, oxidative stress becomes

Table 2. Food and Nutrient Intake according to High Fat-low Carbohydrate Diet Score

	Intake of Carbohydrate, Total Protein, and Total Fat			Intake of Carbohydrate, Animal Protein, and Animal Fat			Intake of Carbohydrate, Plant Protein, and Plant Fat		
	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5
High Fat-Low Carbohydrate Diet Score									
Median	5	15	25	3	16	25	8	15	21
Interquartile range	4-6	14-16	23-27	1-5	14-17	24-27	7-9	14-16	20-23
No. of participants	3911	4306	4431	3890	4846	4273	4430	3984	4547
Rice and rice product (g/day)	265±217	227±171	196±122	165±194	247±176	223±128	362±168	194±162	163±132
Wheat flour and its product (g/day)	182±202	155±164	104±100	277±217	129±140	85±88	62±104	181±180	165±150
Fruit and vegetable (g/day)	328±190	326±191	339±180	312±186	330±190	339±181	350±192	325±191	321±182
Red meat (g/day)	14.4±28.9	63.0±60.2	109±81.0	3.1±9.9	58.0±46.2	134±82.2	69.8±78.5	63.4±69.9	59.2±60.6
Vegetable cooking oil (g/day)	31.3±24.8	48.4±35.8	49.8±31.9	31.4±29.5	39.3±42.5	38.6±32.0	14.0±24.3	35.1±24.0	63.9±47.5
Calories (kcal/day)	2237±621	2292±689	2104±690	2187±612	2282±694	2204±726	2355±664	2231±660	2192±745
Cereal fiber (g/day)	7.5±5.8	5.5±4.9	3.3±3.7	9.0±6.2	5.0±4.5	3.3±4.0	4.8±4.9	6.3±5.7	4.7±4.7
Glycemic index	67.5±11.7	65.3±11.6	59.0±12.1	63.2±12.2	65.5±12.1	61.4±12.5	72.2±9.1	63.0±12.0	58.3±12.2
Glycemic load	269±87	212±75	134±64	244±85	212±84	148±73	268±85	204±77	146±69
Saturated fat (% of Energy)	8.7±5.4	11.9±8.8	11.1±6.5	8.1±3.9	12.1±8.5	12.0±10.1	12.0±11.2	9.8±6.5	13.4±7.9
Monounsaturated fat (% of Energy)	14.6±8.3	23.0±15.5	23.8±14.2	16.2±10.7	23.7±17.9	23.6±16.6	16.7±12.4	19.7±12.1	31.5±22.1
Polyunsaturated fat (% of Energy)	11.9±7.5	18.4±12.3	23.3±13.4	15.6±9.5	19.6±15.4	19.5±12.8	8.9±5.3	17.6±8.3	30.6±18.0
Carbohydrate (% of Energy)	72.9±4.3	57.9±4.3	42.9±6.8	71.4±5.9	57.5±7.8	43.4±7.6	66.0±9.5	59.0±9.2	45.9±9.4
Total protein (% of Energy)	10.3±1.4	11.6±2.5	14.7±3.0	10.8±1.7	11.7±2.7	14.0±3.6	10.6±2.2	12.2±2.6	13.0±3.7
Animal protein (% of Energy)	0.8±1.0	3.0±2.1	6.7±3.0	0.3±0.5	3.1±1.7	7.0±2.9	2.8±2.5	3.3±3.1	3.9±3.0
Plant protein (% of Energy)	9.5±1.6	8.6±2.0	8.0±2.4	10.5±1.7	8.6±2.0	7.0±2.0	7.8±1.5	8.8±2.1	9.0±2.6
Total fat (% of Energy)	16.7±4.9	30.3±6.4	42.2±7.6	17.6±6.2	30.6±8.9	42.4±8.3	23.2±9.6	28.6±9.1	41.0±10.0
Animal fat (% of Energy)	5.4±6.1	12.0±9.2	16.8±9.0	1.8±2.6	11.3±6.8	22.1±9.0	16.1±11.5	10.8±9.4	9.0±6.8
Plant fat (% of Energy)	11.3±6.2	18.2±9.8	25.4±10.3	15.8±7.3	19.3±12.3	20.3±10.9	7.0±4.8	17.7±5.0	32.0±9.7

Note. Tested trends were all significant (P<0.05) except for the daily calory intake for the animal high-fat-low-carbohydrate-diet score.

Table 3. Characteristics of Participants in This Study according to High Fat-low Carbohydrate Diet Score

	Intake of Carbohydrate, Total Protein, and Total Fat			Intake of Carbohydrate, Animal Protein, and Animal Fat			Intake of Carbohydrate, Plant Protein, and Plant Fat		
	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5
Women (%)	52.8	52.7	51.7	51.9	52.1	51.9	52.0	52.6	51.7
Age (yr)	54.4±6.7	54.4±6.9	55.4±7.2	54.4±6.7	54.8±7.0	54.9±7.0	54.3±6.8	54.6±6.9	55.4±7.1
Sedentary activity time (hours/day)	1.8±1.3	2.3±1.5	3.1±1.8	1.9±1.3	2.4±1.6	3.0±1.8	1.9±1.4	2.4±1.5	2.8±1.8
Smoking (%)	32.6	31.0	28.8	32.2	30.8	29.7	32.8	31.0	29.1
Alcohol drinking (%)	23.2	24.3	24.7	18.4	25.2	26.7	29.4	23.0	22.5
Family income (Yuan/Year/Person)									
<800	25.0	13.5	4.3	25.7	11.4	5.8	19.2	12.2	8.8
800-1999	45.3	29.1	11.5	44.8	27.5	15.3	40.0	31.6	17.5
2000-4999	24.6	32.9	24.9	24.2	32.7	26.3	29.4	28.9	27.7
⩾5 000	5.1	24.5	59.3	5.3	28.4	52.7	11.5	27.4	46.1
Education									
Illiterate	25.6	17.7	6.9	25.5	16.6	8.2	23.8	16.0	11.2
Primary school	47.0	39.3	26.3	43.9	38.9	29.9	46.5	38.3	29.8
Middle school (Junior or senior)	26.8	39.9	56.3	30.1	40.5	52.9	28.6	41.1	51.3
College or above	0.6	3.2	10.6	0.6	4.1	9.0	1.1	4.6	7.8
Low activity level (%)									
Low	22.1	43.2	78.1	23.7	47.5	72.1	27.3	48.1	65.7
Medium	28.4	24.7	14.1	29.9	22.5	15.2	25.8	23.6	18.3
High	49.5	32.2	7.8	46.4	30.0	12.7	47.0	28.3	16.1
Body mass index (kg/m^2)[1]	23.3±3.7	23.7±3.5	23.8±3.9	23.8±3.7	23.6±3.5	23.3±3.7	22.7±3.6	23.7±3.5	24.1±3.6
Low density lipoprotein (mmol/L)[1]	2.09±0.83	2.19±0.79	2.36±0.86	2.07±0.83	2.22±0.0.79	2.35±0.83	2.22±0.82	2.20±0.79	2.28±0.81
High density lipoprotein (mmol/L)[1]	1.27±0.34	1.32±0.32	1.34±0.35	1.25±0.34	1.33±0.0.32	1.37±0.34	1.34±0.34	1.30±0.32	1.31±0.33
Triglyceride (mmol/L)[1]	1.27±0.85	1.24±0.80	1.20±0.88	1.29±0.84	1.23±0.80	1.18±0.85	1.22±0.83	1.24±0.80	1.25±0.82
Systolic blood pressure (mmHg)[1]	130.3±23.0	130.3±21.7	128.0±23.7	131.3±22.7	129.3±21.7	127.0±22.9	127.5±22.4	130.1±21.7	130.2±22.3
Diastolic blood pressure (mmHg)[1]	81.5±12.9	81.6±12.1	81.1±13.3	82.3±12.7	81.2±12.1	80.4±12.8	79.9±12.6	81.6±12.1	82.0±12.4

Note. [1]Adjusted means and SD, other variables in the model included sex, age in 5-y categories, current smoking (yes *vs*. no), and current drinking (yes *vs*. no), sedentary activity time in 1-h categories, family history of type 2 diabetes, family income level (four categories: <800, 800-1999, 2000-4999, ⩾5 000 Yuan/Person/year), educational level (four categories: illiterate, primary school, middle school, colleague/university or above). Tested trends were all significant ($P<0.05$) except for triglyceride for the plant high-fat-low-carbohydrate-diet score.

Table 4. Odds Ratio (95% CI) of Newly Diagnosed Hyperglycaemia and Type 2 Diabetes according to High Fat-low Carbohydrate Diet Score

High Fat-low Carbohydrate Diet Score	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	*P* for Trends
	1	3	5	8	10	
TYPE 2 DIABETES						
By total carbohydrate, total protein, and total fat						
Age and sex adjusted	1.0	1.73 (1.29-2.32)	1.83 (1.36-2.45)	2.03 (1.52-2.73)	2.75 (2.09-3.61)	<.0001
Multivariate adjusted[1]	1.0	1.62 (1.19-2.21)	1.54 (1.13-2.11)	1.63 (1.18-2.24)	1.87 (1.36-2.58)	0.0015
Multivariate plus BMI[2]	1.0	1.58 (1.16-2.16)	1.43 (1.04-1.96)	1.53 (1.10-2.11)	1.73 (1.25-2.45)	0.0080
Multivariate plus BMI, SBP, TG,HDL, LDL[3]	1.0	1.54 (1.11-2.14)	1.48 (1.05-2.96)	1.66 (1.18-2.33)	1.86 (1.32-2.61)	0.0015
By total carbohydrate, animal protein, and animal fat						
Age and sex adjusted	1.0	1.20 (0.91-1.57)	1.34 (1.04-1.74)	1.36 (1.04-1.79)	1.74 (1.36-2.24)	<.0001
Multivariate adjusted[1]	1.0	1.07 (0.81-1.42)	1.00 (0.76-1.32)	0.96 (0.71-1.29)	1.07 (0.80-1.43)	0.8844
Multivariate plus BMI[2]	1.0	1.08 (0.81-1.43)	1.02 (0.77-1.35)	0.99 (0.73-1.33)	1.13 (0.84-1.51)	0.5866
Multivariate plus BMI, SBP, TG,HDL, LDL[3]	1.0	1.09 (0.81-1.47)	1.13 (0.85-1.52)	1.08 (0.79-1.49)	1.23 (0.90-1.68)	0.2476
By total carbohydrate, plant protein, and plant fat						
Age and sex adjusted	1.0	1.35 (1.00-1.83)	2.02 (1.52-2.67)	2.38 (1.81-3.14)	2.65 (2.03-3.44)	<.0001
Multivariate adjusted[1]	1.0	1.32 (0.96-1.81)	1.77 (1.31-2.39)	1.97 (1.46-2.66)	2.16 (1.61-2.88)	<.0001
Multivariate plus BMI[2]	1.0	1.13 (0.82-1.56)	1.49 (1.09-2.81)	1.59 (1.18-2.15)	1.73 (1.29-2.31)	<.0001
Multivariate plus BMI, SBP, TG,HDL, LDL[3]	1.0	1.18 (0.84-1.66)	1.52 (1.10-2.09)	1.69 (1.23-2.32)	1.83 (1.34-2.54)	<.0001
HYPERGLYCAEMIA						
By total carbohydrate, total protein, and total fat						
Age and sex adjusted	1.0	1.43 (1.17-1.76)	1.60 (1.31-1.96)	1.73 (1.41-2.11)	2.31 (1.92-2.79)	<.0001
Multivariate adjusted[1]	1.0	1.35 (1.09-1.66)	1.39 (1.13-1.72)	1.46 (1.17-1.81)	1.72 (1.38-2.14)	<.0001
Multivariate plus BMI[2]	1.0	1.30 (1.06-1.61)	1.29 (1.04-1.65)	1.37 (1.10-1.71)	1.59 (1.27-1.98)	0.0002
Multivariate plus BMI, SBP, TG,HDL, LDL[3]	1.0	1.29 (1.04-1.61)	1.32 (1.06-1.64)	1.44 (1.15-1.81)	1.63 (1.29-2.45)	<.0001
By total carbohydrate, animal protein, and animal fat						
Age and sex adjusted	1.0	1.15 (0.94-1.45)	1.34 (1.11-1.62)	1.43 (1.18-1.73)	1.69 (1.40-2.72)	<.0001
Multivariate adjusted[1]	1.0	1.04 (0.85-1.27)	1.08 (0.89-1.31)	1.09 (0.88-1.34)	1.17 (0.95-1.43)	0.1318
Multivariate plus BMI[2]	1.0	1.05 (0.85-1.28)	1.10 (0.90-1.34)	1.12 (0.91-1.39)	1.23 (1.00-1.52)	0.0376
Multivariate plus BMI, SBP, TG,HDL, LDL[3]	1.0	1.05 (0.85-1.32)	1.16 (0.95-1.42)	1.19 (0.95-1.48)	1.29 (1.03-1.66)	0.0134
By total carbohydrate, plant protein, and plant fat						
Age and sex adjusted	1.0	1.29 (1.06-1.59)	1.72 (1.41-2.99)	2.06 (1.70-2.49)	2.21 (1.84-2.65)	<.0001
Multivariate adjusted[1]	1.0	1.25 (1.01-1.55)	1.56 (1.28-1.92)	1.78 (1.45-2.18)	1.86 (1.53-2.27)	<.0001
Multivariate plus BMI[2]	1.0	1.10 (0.88-1.36)	1.33 (1.08-1.63)	1.45 (1.18-1.79)	1.50 (1.23-1.84)	<.0001
Multivariate plus BMI, SBP, TG,HDL, LDL[3]	1.0	1.13 (0.91-1.42)	1.34 (1.08-1.66)	1.53 (1.23-1.97)	1.55 (1.26-1.91)	<.0001

Note. [1] Odds ratio was adjusted for sex, age in 5-y categories, current smoking (yes *vs.* no), and current drinking (yes *vs.* no), sedentary activity time in 1-h categories, family history of type 2 diabetes, family income level (four categories: <800, 800-1999, 2000-4999, ⩾5000 Yuan/Person/year), educational level (four categories: illiterate, primary school, middle school, colleague/university or above),[2]Further adjusted for BMI (continuous variable in each unit); [3]Further adjusted for BMI, SBP, TG, LDL, HDL (continuous).

Table 5. Stratified Odds Ratio (95% CI)[1] of Newly Diagnosed Hyperglycaemia according to High Fat-low Carbohydrate Diet Score

	Quintile					*P* for Trends	*P* for Interaction
	1	2	3	4	5		
Sex							
Male	1	1.31 (0.94-1.86)	1.31 (0.95-1.81)	1.39 (0.99-1.94)	1.76 (1.26-2.45)	0.0013	0.1254
Female	1	1.31 (0.99-1.74)	1.30 (0.98-1.73)	1.36 (1.01-1.82)	1.44 (1.07-1.94)	0.0382	
Family income (Yuan/Year/Person)							
<2000	1	1.39 (1.07-1.80)	1.11 (0.83-1.48)	1.33 (0.97-1.83)	1.50 (1.05-2.14)	0.0637	0.4763
⩾2000	1	1.23 (0.85-1.77)	1.52 (1.08-2.15)	1.44 (1.01-2.43)	1.74 (1.24-2.44)	0.0004	
Educational level							
Illiterate or primary school	1	1.20 (0.93-1.55)	1.27 (0.98-1.65)	1.41 (1.06-1.86)	1.52 (1.13-2.43)	0.0031	0.2792
Middle school or colleague and above	1	1.52 (1.03-2.24)	1.34 (0.92-1.97)	1.36 (0.92-1.99)	1.70 (1.17-2.47)	0.0189	
Physical activity level							
Low	1	1.26 (0.87-1.82)	1.31 (0.92-1.86)	1.40 (0.99-1.99)	1.65 (1.17-2.33)	0.0010	0.4528
Medium	1	1.48 (0.99-2.26)	1.36 (0.89-2.55)	1.67 (1.07-2.61)	1.36 (0.83-2.22)	0.1555	
High	1	1.26 (0.89-1.79)	1.27 (0.88-1.84)	0.99 (0.60-1.69)	1.72 (1.02-2.91)	0.1963	
Leisure sedentary activity (hours/day)							
<2	1	1.34 (0.97-1.86)	1.18 (0.84-1.68)	1.31 (0.89-1.91)	2.04 (1.40-2.98)	0.0017	0.6684
⩾2	1	1.31 (0.99-1.73)	1.35 (1.03-1.78)	1.37 (1.04-1.82)	1.48 (1.12-1.95)	0.0167	
BMI (kg/m^2)							
⩾24	1	1.40 (1.04-1.87)	1.37 (1.02-1.83)	1.59 (1.19-2.14)	1.61 (1.20-2.16)	0.0027	0.9167
<24	1	1.25 (0.92-1.69)	1.30 (0.95-1.78)	1.07 (0.75-1.52)	1.73 (1.23-2.44)	0.0155	
Hypertension							
Yes	1	1.32 (0.98-1.79)	1.28 (0.95-1.73)	1.40 (1.02-1.91)	1.62 (1.18-2.25)	0.0047	0.9790
No	1	1.27 (0.94-1.72)	1.31 (0.97-1.77)	1.35 (0.98-1.85)	1.59 (1.16-2.18)	0.0077	
High TG							
Yes	1	1.32 (0.88-1.97)	1.52 (1.03-2.25)	1.46 (0.97-2.21)	1.57 (1.04-2.35)	0.0536	0.7896
No	1	1.34 (1.03-1.73)	1.26 (0.97-1.64)	1.51 (1.16-1.96)	1.75 (1.35-2.28)	<.0001	
Low HDL							
Yes	1	1.53 (1.10-2.12)	1.61 (1.16-2.24)	1.65 (1.16-2.34)	1.87 (1.32-2.65)	0.0017	0.3481
No	1	1.16 (0.87-1.54)	1.11 (0.84-1.48)	1.24 (0.92-1.66)	1.42 (1.05-1.97)	0.0176	

Note. [1] Odds ratio was adjusted for sex, age in 5-y categories, current smoking (yes *vs.* no), and current drinking (yes *vs.* no), sedentary activity time in 1-h categories, family history of type 2 diabetes, family income level (four categories: <800, 800-1999, 2000-4999, ⩾5000 Yuan/Person/year), educational level (four categories: illiterate, primary school, middle school, colleague/university or above), BMI and physical activity level (low, medium and high). The stratification variable was excluded from the relative model.

severer in subjects after having a high fat diet, which may impair beta-cell function[16], while high carbohydrate diet may speed up an age-related decline in insulin secretion and lead to an earlier onset of type 2 diabetes because high carbohydrate intake increases the requirement for insulin secretion in order to maintain glucose homeostasis and repeatedly stimulates high insulin output[17]. So the optimal relation of carbohydrate to fat in diet is still a hot topic in human research.

There is evidence that a high carbohydrate intake decreases the prevalence of diabetes[18-19]. It was reported that replacing fat with carbohydrate significantly elevates not only postprandial glucose level but also postprandial and fasting insulin levels in patients with type 2 diabetes when the total energy intake is consistent[20]. However, Bessesen[21] did not find any association between total carbohydrate and diabetes risks after reviewing the updated literature. On the contrast, a prospective study showed that low carbohydrate diets with rich vegetable sources of fat and protein can modestly reduce the risk of diabetes[22]. A recent meta-analysis indicated that replacing saturated fatty acids with carbohydrates with low glucose intolerance values is associated with a lower risk of myocardial infarction, whereas replacing saturated fatty acids with carbohydrates with high glucose intolerance values is associated with a higher risk of myocardial infarction[23]. Their recent pooled analysis of 11 American and European cohort studies showed that decreased risk of coronary events is significantly associated with death due to coronary heart disease and replacement of saturated fat with poly unsaturated fatty acids[24].

Carbohydrate in Chinese diets is commonly characterized and dominated by refined carbohydrate with a high glucose index. Coincidentally, the majority of fat in Chinese diets are MUFA and PUFA. Such a high fat-low carbohydrate diet should potentially protect subjects against type 2 diabetes. However, the high fat-low carbohydrate diet score was significantly associated with the incidence of type 2 diabetes in the present study. It was reported that a higher percentage of energy intake from cereals is associated with a lower trend of diabetes while a higher percentage of energy intake from fat is related with a higher incidence of diabetes in Chinese populations[25].

The question is whether it is just a sign of difference in socioeconomic status in relation with both the dietary pattern and the disease risks. The socioeconomic status, physical activity, and BMI of the subjects should be the major confounders of this association. The multivariate model and stratification analysis showed that the high fat-low carbohydrate diet score was significantly associated with the incidence of type 2 diabetes mellitus, even after adjustment for these variables. The confounding problem may still exist. As the vegetable cooking oil is the main source of fat for people with a high plant fat-low carbohydrate score, it does not depend on the socioeconomic level, at least not as much as the animal high fat-low carbohydrate score, because cooking oil is quite cheap in China. The carbohydrate and animal fat and protein diet score mainly reflects a higher socioeconomic status and a sedentary life style. This assumption, which coincides with the association between type 2 diabetes mellitus and the animal food-based diet score is not significant any more after multivariate adjustment. It was reported that the low carbohydrate diet is associated with the favorable changes in TG and HDL-C levels and the unfavorable changes in LDL level[26], which indirectly supports the assumption that the association between diet score and diabetes should not only reflect the different socioeconomic status.

It was reported that subjects with a higher total fat intake (>37%E) do not benefit from MUFA[27], which is consistent with the fact that changes in estimated desaturase activities (derived from plasma FA composition) are related with those in insulin sensitivity only in subjects with a total fat intake <35.5%E[28]. The present study showed that too much consumption of fat, even good fatty acids, would be dangerous. The dietary energy intake from PUFA was over 10% (which is the recommended maximum PUFA intake level[29]) in the subjects with the lowest high fat-low carbohydrate diet score.

The traditional dietary pattern of Chinese populations is characterized by high carbohydrate with very low fat, which is undergoing rapid transition to the high fat dietary pattern in Western countries. This transition would last a period when various dietary patterns coexist and provide the opportunity to study the association between dietary patterns and diabetes mellitus in a large range of exposed factors. As type 2 diabetes is only a recent epidemic in China, the present study offers a good window to study the associated dietary factors. Fifty percent of the subjects with diabetics in this study were not aware of the fact, supporting the assumption that these subjects still have no chance to change their diets due to type 2 diabetes mellitus or dietary treatment. Meanwhile, several weak points in this study should also be noticed. Firstly, oral glucose tolerance was not tested,

which might result in the underestimation of diabetes cases and misclassification of some cases. Yang et al.[5] recently reported that 46.6% of undiagnosed diabetes the cases meet the criteria for elevated 2-hour plasma glucose level in an oral glucose tolerance test but not the criteria for elevated fasting glucose levels. However, the misclassification of diabetes cases may weaken the real association but not overestimation of causes. In addition, the weaknesses of cross-section study design should not be neglected, which may limit any cause relationship linking.

In conclusion, high fat-low carbohydrate diets, which are far different from the traditional Chinese diets and the sedentary lifestyle, are associated with the high incidence of type 2 diabetes in China, even though they may have some beneficial effects on TG and HDL-C levels. Though the cross-sectional design weakens its potential for cause relationship interpretation, it can be used in design of future prospective study and clinical trials.

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