Original Article

Glycemic load is associated with diabetes and prediabetes among middle-aged and elderly adults in Guangzhou, China

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Background and Objectives: Previous studies have obtained conflicting findings regarding the possible associations between glycemic load (GL) indices and diabetes. In the present study, we examined cross-sectional associations between several GL indices, including the total dietary GL, the energy-adjusted GL, and the prevalence of abnormal glucose metabolism, including prediabetes and diabetes. **Methods and Study Design:** This study was conducted in Guangzhou, China from July 2011 to December 2011. It included 2,022 participants (602 men and 1,420 women), between 45 and 75 years of age. The prevalence of abnormal glucose metabolism was compared across the quartiles of GL indices to discover any potential linear correlations. Stratified analysis was conducted according to the body mass index (BMI) and waist circumference (WC) measurements. **Results:** Energy-adjusted GL was positively associated with the prevalence of diabetes and the multivariable-adjusted estimate of the OR comparing the highest versus the lowest quartile was 2.50 (95% CI, 1.49-4.19). For the stratified analysis by sex, BMI or WC, similar associations were observed. For the overweight and obese (BMI ≥24.0 kg/m^2) or centrally obese (WC ≥85 cm for men or ≥80 cm for women) participants, compared to participants in the lowest quartile of energy-adjusted GL, those in the highest quartile showed an increased risk of abnormal glucose metabolism. The OR estimates were 2.25 (95% CI: 1.45-3.52) and 1.54 (95% CI: 1.06-2.25), respectively. **Conclusions:** High dietary energy-adjusted GL is associated with the prevalence of diabetes as well as abnormal glucose metabolism among middle-aged and elderly adults.

Key Words: carbohydrate, glycemic load, prediabetes, diabetes, obesity

INTRODUCTION

According to the latest edition of the Diabetes Atlas published by the International Diabetes Federation, China has the largest population of diabetics in the world.[1] One recent study showed that 11.6 percent of Chinese adults have been diagnosed with diabetes, and 50.1 percent Chinese adults are at the risk of developing the disease. This suggests there are up to 113.9 million Chinese adults are living with diabetes. An additional 493.4 million people with prediabetes at a high risk for developing the disease. The greater concern is that the prevalence of prediabetes and diabetes are even higher in older age groups.[2]

The American Diabetes Association (ADA) provides dietary recommendations to prevent the development of the disease among people with diabetes including monitoring the quantity and quality of the carbohydrate intake.[3] The ADA has stated that the use of the glycemic index (GI) and glycemic load (GL) as measurements of carbohydrate quality may provide a modest additional benefit compared to carbohydrate counting alone. The GI is a relative ranking of the postprandial blood glucose level for each carbohydrate-containing food when compared to 50 g of glucose or a reference food, and the GL is a measurement of the quantity of a carbohydrate in addition to its quality. Though controversial, the GL value has been hypothesized to be a predictor of diabetes due to its effects on the blood glucose response. The relationship between GL and diabetes has attracted much attention in the field of nutrition and has been applied in dietary assessment tests worldwide.[4-5]

Overall, evidence regarding the effects of dietary GL on glycemic control remains uncertain and inconclusive. Few investigations have collected GL data from a Chinese population, and these previous studies mainly focused on the association between GL and diabetes instead of prediabetes. The aims of this analysis were therefore to characterize dietary GL indices, including the total GL

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and energy-adjusted GL, for different glucose metabolism states in middle-aged and elderly adults in Guangzhou, China, as well as to run a comprehensive analysis to investigate the association between the GL indices and the prevalence of prediabetes and diabetes. Moreover, we conducted a stratified analysis to determine if this association is consistent in overweight and obese adults.

METHODS

Study population

This study was conducted in Guangzhou, China from July 2011 to December 2011. All eligible adults between the ages of 45 and 75 who had lived in Guangzhou for at least 3 years were recruited. Participants were excluded if they (a) had a previous diagnosis of diabetes, and/or they were using an oral diabetes medication or insulin injection, (b) had a severe impairment of their cardiac, hepatic or renal functions, or (c) had an implausible total energy intake of <600 or >4800 kcal.

This study was approved by Ruijin Hospital Ethics Committee ([2011] No. 14). All participants received a precise explanation of the study and provided written informed consent.

Clinical characteristics and glucose tests

The following characteristics were assessed using a self-administered questionnaire: date of birth, sex (male or female), education (≤9 y or >9 y), current smoking status (yes or no), and current drinking status (yes or no). The metabolic equivalent task (MET) value was calculated for each moderate or heavy physical activity using a compendium of physical activity values.[6] Body height and waist circumference (WC) were measured to the nearest 0.1 cm, and the weight was measured to the nearest 0.1 kg. Standard techniques and mean measurements were used. The body mass index (BMI) was calculated as the weight in kilograms divided by the height in metres squared. Blood samples were collected in all participants after an overnight fast of at least 10 hours. Participants were given a standard 75 g glucose solution, and their plasma glucose was measured 0 and 2 h after administration during the oral glucose tolerance test (OGTT).

Dietary assessment

Dietary intake was assessed using a continuous 3-day diet record. Subjects recorded the amount and types of food as well as the drinks that they consumed during a continuous 3-day period, in which one holiday could be included. The daily eating pattern was recorded in detail, especially for carbohydrate-containing foods and drinks. The brand name and preparation method for each food was described specifically. 2 weeks after the glucose test, participants returned to the hospital for collection of their dietary records. All the dietary records were checked by a dietitian before collection. Food models and measuring displays were used to determinate the typical serving sizes.

The Food Composition Table of China (2002)[7] and 2008 international tables[8] of GI were used to establish a software model for logging, calculating, and saving the GI and GL values for the foods consumed by our study population. An appropriate GI value was chosen based on the cooking method used (e.g. uncooked, boiled and fried). The mean value of GI was performed when multiple values were available. For foods without a published GI value, we imputed the GI value in accordance with the most similar foods based on the macronutrient and fiber content as well as the preparation method. The GL for each food was calculated by multiplying the carbohydrate content in each serving by the GI of that food, and the dietary total GL was the sum of all the GL values for each food consumed over the course of one day. The overall dietary GI was obtained by dividing the total GL by the total amount of carbohydrate intake in grams per day. In addition, the total GL was transformed into energy-adjusted values (/1000 kcal) using the residual method.[9]

A dietary diversity score (DDS) was defined as the total count of different food groups irrespective of the amount consumed by individuals over the continuous 3-day period.[10] All the food items consumed by the subjects were categorized into 10 food groups which were refined grains, whole grains, tubers, vegetables, fruits, meat and poultry, fish and seafood, eggs, milk and milk products, bean and nuts. The choice of the 10 food groups was based on the Food Guide Pagoda for Chinese Residents (2016).[11] 1 point was given for each food group consumed and added up to a maximum of 10 if all food groups were consumed.

Definition

Different glucose metabolism states were defined as follows. (a) Diabetes was defined as having a fasting plasma glucose of (FPG) ≥7.0 mmol/L, and/or a 2-hour postprandial plasma glucose of (2hPG) ≥11.1 mmol/L after OGTT. (b) Prediabetes was defined as having an FPG between 6.1-6.9 mmol/L, and/or a 2hPG between 7.8-11.0 mmol/L after OGTT. (c) Normal glucose tolerance was defined as anyone not falling into the above two categories. Both diabetes and prediabetes patients were defined as having abnormal glucose metabolism.

Overweight patients had BMI values between 18.5-23.9 kg/m^2, and obese patients had values of BMI ≥28.0 kg/m^2. Central obesity was defined as WC ≥85 cm for men and ≥80 cm for women.

Data analysis

Statistical analysis was performed using the SAS software system. Two-sided p values <0.05 were considered to be statistically significant. The general characteristics of the study population were expressed as the "mean" for continuous variables, which were compared using ANOVA, or as a "percentage" for categorical variables, which were compared using the chi-square test. We conducted analyses according to the quartiles of dietary GL indices and stratified analyses by BMI and WC categories. Logistic regression was used to assess the association between the GL indices and the prevalence of prediabetes and diabetes.

RESULTS

A total of 2,022 participants were selected as the study sample, including 602 (30%) men and 1,420 (70%) women with a mean age of 56 years. In the study population, 770 and 178 participants were categorized as falling into the prediabetes and diabetes groups, respectively. Prediabetes patients accounted for 38% of the participants, while diabetes patients accounted for 9% of the participants. The mean dietary total GL of the study population was 181, and the mean energy-adjusted GL was 96. Cereals were the dominant source of dietary total GL across all glucose metabolism status groups, accounting for approximately 90% of the dietary total GL. Participants with diabetes and prediabetes showed higher dietary GL values than those with normal glucose tolerance levels, including total GL (185, 185 and 178, respectively, p=0.02) and energy-adjusted GL (101, 96 and 95, respectively, p<0.01).

The results showed that men tended to have a higher dietary GL, including total GL and energy-adjusted GL. Participants in the higher quartile of total GL were older, have less education, and were more likely to be current smoking and drinking compared to those in the lowest quartile; however, no significant trend was observed with energy-adjusted GL increased. Dietary carbohydrate intake and GI were positively associated with both GL indices while the intake of fat, protein and insoluble dietary fiber were positively associated with total GL but negatively associated with energy-adjusted GL. Participants with higher energy-adjusted GL scored lower diet diversity (Table 1).

No significant association was observed between the total GL and the prevalence of diabetes or abnormal glucose metabolism. However, the replacement of total GL with energy-adjusted GL was significantly associated with the prevalence of both diabetes and abnormal glucose metabolism. The multivariable-adjusted ORs across quartiles of energy-adjusted GL were 1.00, 1.55, 2.02 (95% CI, 1.21-3.37), and 2.50 (95% CI, 1.49-4.19) for diabetes, and 1.00, 1.12, 1.06, and 1.39 (95% CI, 1.05-1.83) for abnormal glucose metabolism. Similar results were observed in stratified analysis according to patient sex (Table 2).

In our population, having a higher BMI (≥24.0 kg/m^2) or a larger WC (≥85 cm for men or ≥80 cm for women) was associated with higher risk of developing diabetes (OR [95% CI], 2.10 [1.54-2.86] and 2.16 [1.55-3.00], respectively). Therefore, we conducted stratified analyses based on the categories of BMI and WC, respectively. Association between diabetes and the total GL was observed only in the participants who were not overweight or obese. However, high energy-adjusted GL was associated with a significantly higher prevalence of diabetes in the participants with or without an overweight or obese status. Moreover, in the subgroup with a BMI above 24.0 kg/m^2, an elevated prevalence of both diabetes and abnormal glucose metabolism were observed as the energy-adjusted GL increased (Table 3). Similarly, significant associations were observed in the analysis stratified by WC (Table 4).

DISCUSSION

To our knowledge, no existing cross-sectional or cohort community-based study has investigated dietary GL in Guangzhou or China. In the present study, refined grain and vegetable consumption was 100%, which differ significantly from their counterparts in the US and Europe. The present study therefore assessed an Asian population and demonstrated that the mean energy-adjusted GL value was 96 in Guangzhou, China, which was higher than the values (range, 79-88) reported in Japan.[12-13] Moreover, while several previous studies used information collected from self-administered questionnaires, our study was based on more reliable information obtained from medical examinations and FPG and 2hPG after OGTT.

Dietary GL is a reflection of the categories and amounts of carbohydrates in daily foods, making up for the shortfall of GI that only reflects the carbohydrates present in a single food. However, given that the fat, pro-

Table 1. General characteristics of the middle-aged and elderly adults from Guangzhou by quartiles of GL indices (n=2,022)

Characteristic	Total GL					Energy-adjusted GL				
	Q1	Q2	Q3	Q4	p	Q1	Q2	Q3	Q4	p
Dietary data										
Energy, kcal/d	1496	1730	1967	2363	<0.01	1902	1822	1892	1940	<0.01
Carbohydrate, g/d	179	222	266	342	<0.01	220	235	262	291	<0.01
Fat, g/d	58	61	65	69	<0.01	75	64	61	54	<0.01
Protein, g/d	65	73	79	92	<0.01	86	77	75	72	<0.01
Insoluble dietary fiber, g/d	10	12	13	14	<0.01	13	12	12	11	<0.01
GI	70	71	72	75	<0.01	68	71	73	76	<0.01
DDS	6.7	7.2	7.3	7.0	0.02	7.4	7.3	6.9	6.3	<0.01
Other data										
Male, %	10.3	15.5	27.3	66.1	<0.01	16.3	22.1	34.4	46.1	<0.01
Age, y	55.5	55.4	55.7	57.0	<0.01	55.5	55.9	55.9	56.4	0.14
Moderate/heavy physical activity, METs/w	31.9	27.8	35.3	25.8	0.01	32.3	31.6	29.6	27.3	0.37
Education, >9 y, %	67.2	63.1	68.4	57.3	<0.01	69.3	64.0	65.2	57.5	<0.01
Overweight or obesity, %	39.5	45.2	38.3	39.5	0.11	40.2	40.3	42.3	39.8	0.85
Central obesity, %	50.2	57.5	52.2	47.4	0.01	49.4	53.8	51.0	53.2	0.49
Current smoking, %	7.1	8.7	13.8	28.5	<0.01	10.0	10.0	19.8	18.5	<0.01
Current drinking, %	2.4	5.6	6.3	9.5	<0.01	5.6	5.5	7.1	5.5	0.64

Q: quartile; GL: glycemic load; GI: glycemic index; DDS: dietary diversity score; MET: metabolic equivalents.
Data are presented as the means or percentages.

Table 2. Association between dietary GL indices and abnormal glucose metabolism prevalence in middle-aged and elderly adults from Guangzhou

	Total GL					Energy-adjusted GL				
	Q1	Q2	Q3	Q4	*p* for trend	Q1	Q2	Q3	Q4	*p* for trend
Participants (n=2,022)										
Diabetes										
Age, sex adjusted	1.00	0.67 (0.41-1.09)	1.47 (0.96-2.25)	0.84 (0.49-1.45)	0.29	1.00	1.46 (0.88-2.43)	1.89 (1.16-3.09)	2.26 (1.39-3.69)	<0.01
Multivariate†	1.00	0.59 (0.35-0.97)	1.55 (1.00-2.41)	0.86 (0.49-1.53)	0.18	1.00	1.55 (0.92-2.60)	2.02 (1.21-3.37)	2.50 (1.49-4.19)	<0.01
Abnormal glucose metabolism										
Age, sex adjusted	1.00	1.19 (0.93-1.53)	1.41 (1.09-1.82)	1.17 (0.86-1.58)	0.08	1.00	1.08 (0.84-1.39)	1.06 (0.82-1.37)	1.31 (1.01-1.70)	0.04
Multivariate†	1.00	1.15 (0.89-1.49)	1.38 (1.05-1.80)	1.14 (0.83-1.57)	0.05	1.00	1.12 (0.86-1.45)	1.06 (0.82-1.38)	1.39 (1.05-1.83)	0.02
Men (n=602)										
Diabetes										
Age adjusted	1.00	1.19 (0.51-2.79)	1.16 (0.52-2.61)	1.59 (0.74-3.44)	0.23	1.00	1.96 (0.79-4.87)	1.27 (0.49-3.34)	3.44 (1.49-7.94)	<0.01
Multivariate†	1.00	1.37 (0.53-3.55)	1.62 (0.63-4.21)	1.24 (0.52-2.97)	0.37	1.00	1.81 (0.67-4.87)	1.51 (0.54-4.20)	3.99 (1.52-10.48)	0.03
Abnormal glucose metabolism										
Age adjusted	1.00	0.90 (0.57-1.42)	0.60 (0.38-0.95)	1.40 (0.88-2.21)	0.45	1.00	1.16 (0.74-1.84)	0.67 (0.43-1.06)	1.24 (0.79-1.95)	0.85
Multivariate†	1.00	1.01 (0.62-1.64)	0.62 (0.38-1.01)	1.48 (0.92-2.40)	0.33	1.00	1.30 (0.80-2.10)	0.75 (0.46-1.20)	1.50 (0.91-2.46)	0.83
Women (n=1420)										
Diabetes										
Age adjusted	1.00	0.51 (0.28-0.93)	0.99 (0.58-1.69)	1.20 (0.73-1.95)	0.21	1.00	2.23 (1.15-4.30)	2.80 (1.47-5.33)	3.17 (1.70-5.94)	<0.01
Multivariate†	1.00	0.49 (0.26-0.92)	1.03 (0.59-1.81)	1.15 (0.69-1.91)	0.21	1.00	2.04 (1.03-4.04)	3.14 (1.59-6.20)	3.36 (1.74-6.47)	<0.01
Abnormal glucose metabolism										
Age adjusted	1.00	0.97 (0.72-1.31)	1.19 (0.88-1.61)	1.62 (1.20-2.19)	<0.01	1.00	1.35 (1.00-1.82)	1.25 (0.93-1.69)	1.50 (1.11-2.02)	0.02
Multivariate†	1.00	0.97 (0.71-1.33)	1.19 (0.87-1.62)	1.59 (1.16-2.18)	<0.01	1.00	1.28 (0.94-1.74)	1.19 (0.87-1.62)	1.48 (1.08-2.02)	0.02

Q: quartile; GL: glycemic load.
Data are presented as OR (95% CI).
†Additionally adjusted for BMI (continuous), WC (continuous), moderate/heavy physical activity (continuous), education (≤9 y or >9 y), current smoking status (yes or no) and current drinking status (yes or no).

Table 3. Stratified analysis of the GL indices by BMI with abnormal glucose metabolism prevalence in middle-aged and elderly adults from Guangzhou

	Total GL					Energy-adjusted GL				
	Q1	Q2	Q3	Q4	*p* for trend	Q1	Q2	Q3	Q4	*p* for trend
Normal (n=1,200)										
Diabetes										
Age, sex adjusted	1.00	0.74 (0.29-1.84)	3.58 (1.78-7.21)	2.03 (0.85-4.83)	<0.01	1.00	1.87 (0.84-4.14)	1.94 (0.87-4.31)	3.11 (1.43-6.77)	0.01
Multivariate†	1.00	0.65 (0.24-1.79)	3.90 (1.86-8.19)	2.77 (1.06-7.22)	<0.01	1.00	2.03 (0.88-4.67)	1.98 (0.86-4.60)	4.01 (1.74-9.25)	<0.01
Abnormal glucose metabolism										
Age, sex adjusted	1.00	1.18 (0.84-1.66)	1.43 (1.01-2.02)	0.91 (0.60-1.40)	0.50	1.00	0.86 (0.62-1.20)	1.01 (0.72-1.42)	0.99 (0.70-1.40)	0.83
Multivariate†	1.00	1.20 (0.85-1.69)	1.34 (0.95-1.91)	0.83 (0.54-1.29)	0.55	1.00	0.86 (0.61-1.21)	1.03 (0.73-1.45)	0.98 (0.69-1.39)	0.70
Overweight or obesity‡ (n=822)										
Diabetes										
Age, sex adjusted	1.00	0.56 (0.31-1.02)	0.65 (0.36-1.18)	0.51 (0.25-1.04)	0.24	1.00	1.27 (0.65-2.47)	1.74 (0.93-3.29)	1.86 (0.98-3.54)	0.01
Multivariate†	1.00	0.58 (0.32-1.07)	0.68 (0.67-1.23)	0.53 (0.26-1.07)	0.21	1.00	1.24 (0.63-2.45)	1.71 (0.90-3.25)	1.85 (0.95-3.61)	0.02
Abnormal glucose metabolism										
Age, sex adjusted	1.00	1.01 (0.68-1.49)	1.52 (1.02-2.27)	1.40 (0.87-2.24)	0.05	1.00	1.48 (1.00-2.19)	1.26 (0.85-1.87)	1.95 (1.28-2.98)	<0.01
Multivariate†	1.00	1.03 (0.69-1.52)	1.55 (1.03-2.34)	1.45 (0.89-2.34)	0.04	1.00	1.68 (1.12-2.53)	1.32 (0.88-1.96)	2.25 (1.45-3.52)	<0.01

Q: quartile; GL: glycemic load; BMI: body mass index. Data are presented as OR (95% CI).
†Additionally adjusted for moderate/heavy physical activity (continuous), education (≤9 y or >9 y), current smoking status (yes or no) and current drinking status (yes or no). ‡Defined as BMI ≥24.0 kg/m^2.

Table 4. Stratified analysis of the GL indices by WC with abnormal glucose metabolism prevalence in middle-aged and elderly adults from Guangzhou

	Total GL					Energy-adjusted GL				
	Q1	Q2	Q3	Q4	*p* for trend	Q1	Q2	Q3	Q4	*p* for trend
Normal (n=974)										
Diabetes										
Age, sex adjusted	1.00	0.88 (0.34-2.27)	2.72 (1.24-5.98)	1.30 (0.44-3.86)	0.03	1.00	2.39 (0.88-6.43)	1.71 (0.59-4.94)	5.32 (2.07-13.69)	<0.01
Multivariate†	1.00	1.22 (0.43-3.41)	2.72 (1.23-6.04)	1.78 (0.55-5.74)	0.02	1.00	2.28 (0.81-6.40)	1.92 (0.65-5.67)	6.48 (2.41-17.39)	<0.01
Abnormal glucose metabolism										
Age, sex adjusted	1.00	1.24 (0.85-1.81)	1.44 (0.98-2.12)	1.00 (0.61-1.65)	0.58	1.00	1.13 (0.77-1.66)	1.06 (0.71-1.57)	1.31 (0.88-1.95)	0.35
Multivariate†	1.00	1.29 (0.88-1.90)	1.41 (0.95-2.08)	0.94 (0.56-1.57)	0.60	1.00	1.16 (0.79-1.71)	1.08 (0.72-1.60)	1.31 (0.87-1.97)	0.27
Central obesity‡ (n=1,048)										
Diabetes										
Age, sex adjusted	1.00	0.56 (0.32-1.00)	1.00 (0.60-1.68)	0.67 (0.37-1.24)	0.56	1.00	1.16 (0.62-2.14)	1.84 (1.05-3.21)	1.83 (1.03-3.27)	<0.01
Multivariate†	1.00	0.57 (0.32-1.01)	0.99 (0.59-1.66)	0.66 (0.35-1.25)	0.50	1.00	1.16 (0.62-2.16)	1.85 (1.05-3.24)	1.90 (1.05-3.45)	0.01
Abnormal glucose metabolism										
Age, sex adjusted	1.00	1.05 (0.74-1.48)	1.43 (1.01-2.03)	1.22 (0.82-1.82)	0.09	1.00	1.10 (0.78-1.55)	1.26 (0.89-1.78)	1.31 (0.92-1.88)	0.06
Multivariate†	1.00	1.04 (0.74-1.47)	1.34 (0.94-1.92)	1.22 (0.81-1.83)	0.09	1.00	1.17 (0.81-1.67)	1.31 (0.92-1.87)	1.54 (1.06-2.25)	0.02

Q: quartile; GL: glycemic load; WC: waist circumference. Data are presented as OR (95% CI).
†Additionally adjusted for moderate/heavy physical activity (continuous), education (≤9 y or >9 y), current smoking status (yes or no) and current drinking status (yes or no). ‡Defined as WC ≥85 cm for men and ≥80 cm for women.

tein and insoluble dietary fiber intake increased markedly as the total GL increased, the associations between diabetes and total GL were inconclusive in the present study; indeed, a positive association was observed in the participants with normal weights, but disappeared in obese participants. Several existing studies, which used the total GL as a key variable, showed that the dietary GL was not associated with a higher risk of diabetes.[14-17]

The energy-adjusted GL was calculated in our study. This is the GL with the same amount of energy intake (1000 kcal), increased the predictive ability, and minimized the influence of confounding factors.[9] Moreover, numerous dietary guidelines emphasize the critical role of the consumption of a diet that is varied and includes different foods from different food groups. Participants with lower energy-adjusted GL were likely to consume more groups of food, which could support individuals in achieving a healthy balanced diet.

In our study, higher dietary energy-adjusted GL values were associated with an increasing prevalence of diabetes, which was consistent the results of several existing studies.[18-19] However, several studies conducted in patients of different ages or with different glucose metabolism states reported conflicted findings.[20-21] Moreover, our study also showed that higher dietary energy-adjusted GL was also associated with the prevalence of abnormal glucose metabolism, including diabetes and prediabetes. Given that prediabetic patients are at a high risk of developing diabetes, the associations between prediabetes and the dietary GL indices have also attracted attention. Taken together, the superiority of the dietary GL indices in the prevalence of abnormal glucose metabolism still remain an open research question.

The evaluation of dietary GL is tightly related to its specific food origin. Therefore, the application of dietary GL in guiding food selection among patients must take the specific disease and detailed food origin into consideration. In the preceding study, subjects who had previously been diagnosed with diabetes were found to have made some dietary modifications towards improved carbohydrate quality, as a KAP-changing (Knowledge, Attitude, Practice) consequence of disease.[22] It led to several health-related behavioural changes, such as a lower carbohydrate intake, a reduced consumption of cereal, especially middle and high GI cereals, and/or an increasing consumption of vegetable and legumes. In our study, participants with known diabetes or who were being treated for diabetes were excluded in order to rule out the possibility of dietary modification.

In our study, the dietary GL was assessed by a typical continuous 3-day diet record instead of a food frequency questionnaire (FFQ). This was done because the structure of FFQ is not optimal for the assessment of GI and GL. Although the 3-day diet record sometimes underestimates the food intake, the cereal intake, which was the dominant source of dietary GL, rarely changes unless diet control treatment is initiated. Moreover, the promising results of the 3-day diet record allowed us to improve the precision of the estimation of dietary carbohydrates and to provide data on meal patterns. Recording the dietary details in the 2 weeks following the first interview, instead of reviewing past dietary details, reduced the chances of subjective bias caused by poor memory. Since information on the occurrence of diabetes or prediabetes was obtained, and dietary exposure was independently classified, the risk of information bias was greatly reduced.

This research had several limitations. The cross-sectional design was based on a relatively small sample size, and convenience sampling was used, such that adults who were employed may have been excluded. Therefore, the prevalence of abnormal glucose metabolism in our sample may have been differed from that of the general population. Another limitation was the lack of data on the prevalence of other chronic metabolic disease, which may also lead to changes in the dietary pattern. A further limitation of the present study was that for some foods, the exact GI value was not available; thus, GI assignments were based on imputed values from similar foods or estimated using mixed-meal calculations.

Conclusions

Our study supports the hypothesis that the type or quality of carbohydrate eaten plays an important role in the aetiology of diabetes among middle-aged and elderly Chinese adults. These findings and those of similar studies suggest that high dietary energy-adjusted GL, instead of total GL, is associated with the risk of developing prediabetes and diabetes. However, more robust longitudinal studies are needed to elucidate the sustainability of a low-GL diet and the relationship linking diabetes or prediabetes incidence and GL intake over time.

AUTHOR DISCLOSURES

The authors declare no conflict of interest.

REFERENCES

1. International Diabetes Federation. IDF Diabetes Atlas (Sixth edition). 2013. [cited 2013/05]; Available from: http://www.idf.org/diabetesatlas.
2. Xu Y, Wang L, He J, Bi Y, Li M, Wang T et al. Prevalence and control of diabetes in Chinese adults. JAMA. 2013;310: 948-58. doi: 10.1001/jama.2013.168118.
3. American Diabetes Association, Bantle JP, Wylie-Rosett J, Albright AL, Apovian CM, Clark NG et al. Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. Diabetes Care. 2008;31:61-78. doi: 10.2337/dc08-S061.
4. Weber C, Schnell O. The assessment of glycemic variability and its impact on diabetes-related complications: an overview. Diabetes Technol Ther. 2009;11:623-33. doi: 10.1089/dia.2009.0043.
5. O'Reilly J, Wong SH, Chen Y. Glycaemic index, glycaemic load and exercise performance. Sports Med. 2010;40:27-39. doi: 10.2165/11319660-000000000-00000.
6. Ainsworth BE, Haskell WL, Whitt MC, Inwin ML, Swartz AM, Strath SJ et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc. 2000;32:S498-504.
7. Yang Y, Wang G, Pan X. China Food Composition 2002. Beijing: Peking University Medical Press; 2002. pp. 335-7.
8. Atkinson FS, Foster-Powell K, Brand-Miller JC. International tables of glycemic index and glycemic load values: 2008. Diabetes Care. 2008;31:2281-3. doi: 10.2337/dc08-1239.
9. Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. Am J Clin Nutr. 1997;65:1220S-31S.

10. Lee MS, Huang YC, Su HH, Lee MZ, Wahlqvist ML. A simple food quality index predicts mortality in elderly Taiwanese. J Nutr Health Aging. 2011;15:815-21.
11. Chinese Nutrition Society. Chinese dietary guidelines. Beijing: People's Medical Publishing House; 2016. pp. 3.
12. Goto M, Morita A, Goto A, Sasaki S, Aiba N, Shimbo T et al. Dietary glycemic index and glycemic load in relation to HbA1c in Japanese obese adults: a cross-sectional analysis of the Saku Control Obesity Program. Nutrition & Metabolism. 2012;9:79. doi: 10.1186/1743-7075-9-79.
13. Sakurai M, Nakamura K, Miura K, Takamura T, Yoshita K, Morikawa Y et al. Dietary glycemic index and risk of type 2 diabetes mellitus in middle-aged Japanese men. Metabolism. 2012;61:47-55. doi: 10.1016/j.metabol.2011.05.015.
14. Sluijs I, Beulens JW, van der Schouw YT, van der A DL, Buckland G, Kuijsten A et al. Dietary glycemic index, glycemic load, and digestible carbohydrate intake are not associated with risk of type 2 diabetes in eight European countries. J Nutr. 2013;143:93-9. doi: 10.3945/jn.112.165605.
15. Simila ME, Valsta LM, Kontto JP, Albanes D, Virtamo J. Low-, medium- and high- glycemic index carbohydrates and risk of type 2 diabetes in men. Br J Nutr. 2011;105:1258-64. doi: 10.1017/S000711451000485X.
16. Mosdøl A, Witte DR, Frost G, Marmot MG, Brunner EJ. Dietary glycemic index and glycemic load are associated with high-density-lipoprotein cholesterol at baseline but not with increased risk of diabetes in the Whitehall II study. Am J Clin Nutr. 2007;86:988-94.
17. Meyer KA, Kushi LH, Jacobs DR Jr, Slavin J, Sellers TA, Folsom AR. Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. Am J Clin Nutr. 2000;71:921-30.
18. Hopping BN, Erber E, Grandinetti A, Verheus M, Kolonel LN, Maskarinec G. Dietary fiber, magnesium, and glycemic load alter risk of type 2 diabetes in a multiethnic cohort in Hawaii. J Nutr. 2010;140:68-74. doi: 10.3945/jn.109.112441.
19. Rossi M, Turati F, Lagiou P, Trichopoulos D, Augustin LS, La Vecchia C, Trichopoulou A. Mediterranean diet and glycemic load in relation to incidence of type 2 diabetes: results from the Greek cohort of the population-based European Prospective Investigation into Cancer and Nutrition (EPIC). Diabetologia. 2013;56:2405-13. doi: 10.1007/s00125-013-3013-y.
20. Hodge AM, English DR, O'Dea K, Giles GG. Glycemic index and dietary fiber and the risk of type 2 diabetes. Diabetes Care. 2004;27:2701-6.
21. Schulze MB, Liu S, Rimm EB, Manson JE, Willett WC, Hu FB. Glycemic index, glycemic load, and dietary fiber intake and incidence of type 2 diabetes in younger and middle-aged women. Am J Clin Nutr. 2004;80:348-56.
22. Van Rompay MI, McKeown NM, Castaneda-Sceppa C, Ordovas JM, Tucker KL. Carbohydrate nutrition differs by diabetes status and is associated with dyslipidemia in Boston Puerto Rican adults without diabetes. J Nutr. 2013;143:182-8. doi: 10.3945/jn.112.168914.