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ORIGINAL ARTICLE

Dietary patterns and diabetes risk in Southern Chinese in Guangxi Zhuang autonomous region

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Abstract

Background The association between dietary patterns (DPs) and diabetes risk remains inconsistent in terms of intake and frequency.

Objectives To explore the association between dietary patterns (DPs) and diabetes risk.

Methodology We recruited 13,587 volunteers from a cohort study in Guangxi. Principal component analysis was used to define DPs, and logistic regression was used to explore the associations.

Results In both model 1 (grouped by history of diabetes) and model 2 (grouped by current Glu), frequencies of dessert intake and fruit intake are significantly different between people with and without diabetes risk (all $p<0.01$). Uni- and multivariate logistic regression analyses all show that a limited frequency of dessert intake (less than *3–4 times per week*) significantly reduced diabetes risk before or after adjustment in both model 1 and model 2, and a more frequency of fruit intake (more than *3–4 times per week*) significantly decreased diabetes risk in model 1. After sub-analysis by age and sex, the associations between diabetes risk and frequency of dessert intake and fruit intake still exist.

Conclusion The DPs of Southern Chinese in Guangxi were related to food abundance and frequency of intake. Habitual fruit intake and moderate frequencies of sweets were associated with decreased diabetes risk.

Keywords Dietary patterns · Diabetes · Southern Chinese · Principal component analysis · Logistic regression

Introduction

Diabetes brings heavy burden to the global population, including macrovascular and microvascular complications [1]. The overall prevalence of diabetes in China had increased from 1980 to 2013 [2]. The latest nationwide cross-sectional survey in mainland China indicated that the estimated standardized prevalence of diabetes was 10.9% [3].

Up to 90% of diabetes cases worldwide are preventable if individuals follow a healthy diet and lifestyle [4]. In the UK, Conklin et al. indicated that the regular consumption of all five food groups (dairy products, fruits, vegetables, meat and alternatives, and grains) and a greater variety of dairy, fruit, and vegetable subtypes may be important to reduce the risk of diabetes [5]. In China, Sun et al. identified four dietary patterns (DPs), including healthy diet, high-salt diet, meat diet, and carbohydrate-rich diet, and suggested that high-salt diet and carbohydrate-rich diet are positively associated with diabetes risk compared with healthy diet [6]. Characteristic DPs, such as the Mediterranean diet (MeDiet), have been confirmed to reduce the incidence of cardiovascular disease by 30% [7]. Adherence to the MeDiet and Dietary Approaches to Stop Hypertension is associated with a remarkable reduction in the risk of incident diabetes [8]. However, DPs in the Chinese population may be difficult to derive from a

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consistent standard because of the great difference in the eating habits among different ethnicities [9, 10].

There is a certain relationship existing between diet and diabetes, and regional differences in dietary behavior. To date, conclusions on the relationship between diet and diabetes risk are still inconsistent. A previous study in Guangxi evaluated the influence of dietary habit such as dietary laws, diet tastes, and cooking methods [11]. The present study is based on a Guangxi Zhuang prospective cohort and aims to explore the association between DPs and diabetes risk. As supplementary evidence, it could alert us to formulate a targeted disease management meal plan for populations.

Methods

Study population

The studied population is from the baseline survey data of local residents in Guangxi of the Prospective Cohort Study of Chronic Diseases in Natural Populations in South China from May 2, 2018, to November 6, 2019. Volunteers were aged 30–82 years. Included individuals were Guangxi permanent residents (validated by identity card or household register).

Diabetes diagnosis and assessment

History of diabetes was investigated, and blood glucose (Glu) of the study population was determined with morning fasting blood using the Roche® C702 biochemical analyzer. Model 1 is grouped by self-reported history of diabetes. Model 2 is grouped by Glu value. Diabetes risk assessment methods refer to the guidelines by the Chinese Diabetes Society [12].

Assessment of diet and covariates

A self-designed, simplified food frequency questionnaire (FFQ) was used during face-to-face interview. The FFQ used in this study was consistent with FFQ25, which was validated in populations all over the world previously [13]. The content of FFQ was shown in the Supplementary file. Participants provided standardized answers to the investigators, selecting from six food frequency categories, that is, *< 1 time per month*, *≤3 times per month*, *1–2 times per week*, *3–4 times per week*, *5–6 times per week*, and *everyday*, which were assigned range from 0 to 5. In the logistic regression analysis, *< 1 time per month* is always a reference. Trained physicians measured subjects' body composition using the TANITA BC-601 Body Fat Monitor. The subjects stood on the instrument with both hands clasping the handle. After the instrument automatically measured, it directly read the subject's body composition data, including height, weight, BMI, body fat percentage, body water, visceral fat, body age, and other indicators.

Statistical analysis

DPs were derived by PCA using R 3.6.3 software (visualize with RStudio). Packages *readxl* and *xlsx* were for importing and exporting data, package *dplyr* was for data cleaning, packages *Hmisc* and *psych* were for statistical description and PCA, the built-in function *glm()* was for uni- (ULR) and multi- (MLR) variate logistic regression, package *CATT* was for Cochran–Armitage trend test, and packages *forestplot* and *ggbiplot* was for plotting. *T* test or one-way ANOVA was used for measurement data, whereas chi-squared test was used for counting data. Nonparametric test was used when variance was not homogeneous. Two-tailed p value less than 0.05 was defined as significant. Data were described as mean ± standard deviation (SD) or number (N) with percentage (%).

Results

Demographics

The cohort included 13,587 participants with complete records of the questionnaire, physical examination, and laboratory data. After credibility evaluation of questionnaires and data cleaning, we enrolled participants with high reliability and complete information. Over 93.7% participants are of Zhuang ethnicity, and their eating habit is representative of the Zhuang. The flow chart of the participant screening process is shown in Figure S1. Demographic data are shown in Table 1.

DP evaluation

Dietary food items were divided into 14 categories (Table S1). The parallel testing suggested four principal components (PCs) to be involved, and cumulative proportion of the top three PCs (i.e., DPs) exceeded 0.8 (Fig. 1). DP1, DP2, and DP3 were separately named Balanced, Basic, and Insufficient. The DPs in models 1 and 2 are consistent with each other. DP1 contains a wide variety of nutrients, including pasta (0.57), grains (0.47), desserts (0.46), poultry (0.44), seafood (0.48), eggs (0.57), fruit (0.45), nuts (0.49), and milk (0.54). DP2 contains basic nutrients, including livestock (0.47), poultry (0.53), seafood (0.45), and vegetables (0.50), with a less grain intake frequency (−0.40). DP3 contains limited nutrients, only including livestock (0.50) and vegetables (0.43), with a less pickles intake frequency (−0.40). The PCA result also suggested that the population with DP2 has less grain intake and the population with DP3 has less pickle intake.

Table 1 Demographic data of the studied population

Items	Model 1 (N=10,972)		Model 2 (N=10,622)	
	N/mean±SD	*%*	*N/mean±SD*	*%*
Age	54.58±10.41		54.51±10.40	
<60	7,283	66.4%	7,075	66.6%
≥60	3,689	33.6%	3,547	33.4%
Sex				
Male	5,048	46.0%	4,868	45.8%
Female	5,924	54.0%	5,754	54.2%
Education				
No formal schooling	1,430	13.0%	1,371	12.9%
Primary school	4,293	39.1%	4,177	39.3%
Junior high school	3,206	29.2%	3,113	29.3%
High school	1,394	12.7%	1,337	12.6%
College	412	3.8%	396	3.7%
University	230	2.1%	221	2.1%
Postgraduate and above	7	0.1%	7	0.1%
Occupation				
Farmer	6,061	55.2%	5,896	55.5%
Worker	1,266	11.5%	1,218	11.5%
Administrative and management personnel	276	2.5%	262	2.5%
Professional and technical personnel	229	2.1%	220	2.1%
Sales and service staff	219	2.0%	217	2.0%
Private owner	220	2.0%	217	2.0%
Housewife/husband	618	5.6%	595	5.6%
Unemployed/laid-off	274	2.5%	271	2.6%
Others	493	4.5%	478	4.5%
Retired	1,316	12.0%	1,248	11.7%
Marital status				
Married	9,746	88.8%	9,441	88.9%
Widowed	907	8.3%	878	8.3%
Divorce	190	1.7%	181	1.7%
Unmarried	129	1.2%	122	1.1%
Income				
<￥10,000	2,105	19.2%	2,042	19.2%
￥10,000~29,900	3,899	35.5%	3,781	35.6%
￥30,000~59,900	2,589	23.6%	2,506	23.6%
￥60,000~99,900	1,375	12.5%	1,328	12.5%
￥100,000~149,900	794	7.2%	765	7.2%
￥150,000~299,900	187	1.7%	178	1.7%
>￥3000,000	23	0.2%	22	0.2%
Family history of NCD				
No	9,006	82.1%	8,726	82.2%
Yes	1,966	17.9%	1,896	17.8%
Diseases affecting bowel function				
No	10,299	93.9%	9,967	93.8%
Yes	673	6.1%	655	6.2%
BMI	25.53±3.54		23.50±3.52	
Healthy	2,641	24.1%	2,590	24.4%

Table 1 (continued)

Items	Model 1 (N=10,972)		Model 2 (N=10,622)	
	N/mean±SD	*%*	*N/mean±SD*	*%*
Warning	5,263	48.0%	5,097	48.0%
More	2,353	21.4%	2,265	21.3%
Overmuch	715	6.5%	670	6.3%
Glu	4.97±1.40		4.94±1.40	
With history of diabetes	10,618	96.8%	*N/A*	*N/A*
Without history of diabetes	354	3.2%		
Model 2				
3.8~6.1mmol/L	*N/A*	*N/A*	10,121	95.3%
≥ 7.0mmol/L			501	4.7%

Differences between Southern Chinese with or without diabetes risk

In model 1, the distribution of age, occupation, family history of non-communicable diseases (NCD), body mass index (BMI), visceral fat level, habit of drinking soup, Glu, intake frequencies of dessert, livestock, fruit, milk, and beverage are significantly different between people with and without history of diabetes (all $p < 0.05$). In model 2, the distribution of age, sex, education, occupation, smoking status, use of health care products, BMI, visceral fat level, alcohol use, habit of drinking soup, Glu, intake frequencies of rice, grain, dessert, seafood, and fruit (p = 0.010) are significantly different between people with and without diabetes risk defined by current Glu

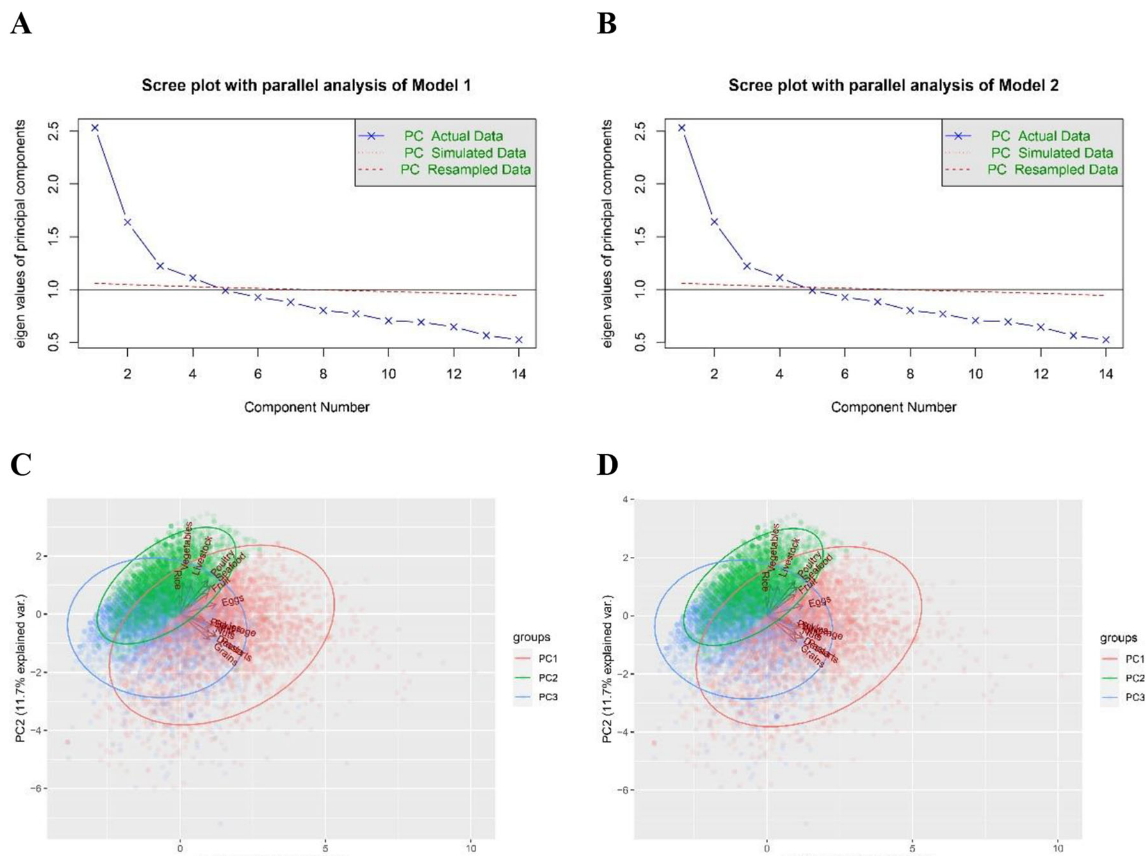

Fig. 1 Principal component analysis. Scree plots with parallel analysis of **a** model 1 and **b** model 2, respectively. PCA results of **c** model 1 and **d** model 2

(all $p < 0.05$). However, in both model 1 and model 2, there is no statistical difference in the distribution of DPs. Therefore, both model 1 and model 2 are sub-analyzed by age, and only model 2 is sub-analyzed by sex (Table S2).

Associations between diet and diabetes risk in Guangxi Southern Chinese

DPs had no significant association with diabetes risk

There was no significant correlation between DPs and diabetes risk in Guangxi residents. The results of the ULR analysis are shown in Figure S2. Dietary variables with $p < 0.05$ were included in MLR analysis (shown in Fig. 2, S3, and Table S3).

Increased pasta, moderate amounts of grains, seafood, and milk were positively associated with diabetes risk

In model 1, increased pasta intake contributed to diabetes risk (*≤3 times per month*: β_{adj} = 0.364, OR_{adj} = 1.439 [1.063–1.943], p_{adj} = 0.018; *1–2 times per week*: β_{adj} = 0.565, OR_{adj} = 1.760 [1.217–2.524], p_{adj} = 0.002; *3–4 times per week*: β_{adj} = 0.494, OR_{adj} = 1.639 [0.998–2.616], p_{adj} = 0.044; *5–6 times per week*: β_{adj} = 0.923, OR_{adj} = 2.518 [1.405–4.333], p_{adj} = 0.001; *everyday*: β_{adj} = 1.049, OR_{adj} = 2.854 [1.671–4.739], p_{adj} < 0.001). Milk intake of *5–6 times per week* was a risk for diabetes (β_{adj} = 1.238, OR_{adj} = 3.449 [1.505–7.113], p_{adj} = 0.002).

In model 2, grain intake of *3–4 times per week* (β_{adj} = 0.538, OR_{adj} = 1.713 [1.154–2.490], p_{adj} = 0.006) and seafood intake of *everyday* (β_{adj} = 0.497, OR_{adj} = 1.643 [1.036–2.552], p_{adj} = 0.030) were associated with increased diabetes risk.

Increased fruit, moderate amounts of rice, desserts, livestock, and beverage were inversely associated with diabetes risk

In model 1, increased fruit intake was inversely associated with diabetes risk (*1–2 times per week*: β_{adj} = −0.630, OR_{adj} = 0.532 [0.349–0.819], p_{adj} = 0.004; *3–4 times per week*: β_{adj} = −0.889, OR_{adj} = 0.411 [0.258–0.655], p_{adj} < 0.001; *5–6 times per week*: β_{adj} = −0.637, OR_{adj} = 0.529 [0.317–0.874], p_{adj} = 0.013; *everyday*: β_{adj} = −0.701, OR_{adj} = 0.496 [0.334–0.747], p_{adj} = 0.001). Moderate amounts of sweets may mitigate diabetes risk, including desserts (*≤3 times per month*: β_{adj} = −0.797, OR_{adj} = 0.450 [0.305–0.647], p_{adj} < 0.001; *3–4 times per week*: β_{adj} = −1.884, OR_{adj} = 0.152 [0.025–0.494], p_{adj} = 0.009), and beverage (*≤3 times per month*: β_{adj} = −0.419, OR_{adj} = 0.658 [0.447–0.945], p_{adj} = 0.028; *1–2 times per week*: β_{adj} = −0.959, OR_{adj} = 0.383 [0.175–0.739], p_{adj} = 0.008). Livestock intake of *5–6 times per week* was also negatively associated with diabetes risk (β_{adj} = −0.701, OR_{adj} = 0.496 [0.278–0.914], p_{adj} = 0.020).

In model 2, a more frequent rice intake was associated with decreased diabetes risk (*5–6 times per week*: β_{adj} = −2.581, OR_{adj} = 0.076 [0.004–0.482], p_{adj} = 0.020; *everyday*: β_{adj} = −0.947, OR_{adj} = 0.388 [0.166–1.068], p_{adj} = 0.043). Moderate desserts were also linked to lower diabetes risk (*≤3 times per month*: β_{adj} = −0.333, OR_{adj} = 0.717 [0.544–0.934], p_{adj} = 0.016; *5–6 times per week*: β_{adj} = −0.991, OR_{adj} = 0.371 [0.144–0.784], p_{adj} = 0.020).

Associations between diet and diabetes risk in adults under 60 years old

In model 1, desserts (*≤3 times per month*: β_{adj} = −0.897, OR_{adj} = 0.408 [0.233–0.671], p_{adj} = 0.001), livestock (*5–6 times per week*: β_{adj} = −0.850, OR_{adj} = 0.427 [0.192–1.026], p_{adj} = 0.044), fruit (*1–2 times per week*: β_{adj} = −0.965, OR_{adj} = 0.381 [0.207–0.718], p_{adj} = 0.002; *3–4 times per week*: β_{adj} = −0.882, OR_{adj} = 0.414 [0.222–0.788], p_{adj} = 0.006; *5–6 times per week*: β_{adj} = −0.952, OR_{adj} = 0.386 [0.185–0.794], p_{adj} = 0.010; *everyday*: β_{adj} = −0.995, OR_{adj} = 0.370 [0.211–0.670], p_{adj} = 0.001), and beverage (*≤3 times per month*: β_{adj} = −0.570, OR_{adj} = 0.565 [0.342–0.900], p_{adj} = 0.021; *1–2 times per week*: β_{adj} = −0.993, OR_{adj} = 0.370 [0.139–0.821], p_{adj} = 0.026) were inversely associated with diabetes risk. But milk (*1–2 times per week*: β_{adj} = 0.745, OR_{adj} = 2.105 [1.051–3.941], p_{adj} = 0.021; *5–6 times per week*: β_{adj} = 1.606, OR_{adj} = 4.983 [1.747–12.089], p_{adj} = 0.001) had positive associations with diabetes risk.

In model 2, dessert intake of *3–4 times per week* was negatively associated with diabetes risk (β_{adj} = −1.118, OR_{adj} = 0.327 [0.097–0.821], p_{adj} = 0.035), while grain intake of *3–4 times per week* was positively associated with diabetes risk (β_{adj} = 0.687, OR_{adj} = 1.987 [1.241–3.112], p_{adj} = 0.003).

Associations between diet and diabetes risk in adults aged 60 and older

In model 1, fruit (*3–4 times per week*: β_{adj} = −1.001, OR_{adj} = 0.368 [0.183–0.721], p_{adj} = 0.004) and pickles (*3–4 times per week*: β_{adj} = −2.060, OR_{adj} = 0.127 [0.007–0.621], p_{adj} = 0.046) both had associations with decreased diabetes risk, while pasta (*5–6 times per week*: β_{adj} = 1.093, OR_{adj} = 2.984 [1.271–6.347], p_{adj} = 0.007; *everyday*: β_{adj} = 1.236, OR_{adj} = 3.441 [1.659–6.658], p_{adj} < 0.001) had associations with increased diabetes risk.

In model 2, moderate amount of desserts (*≤3 times per week*: β_{adj} = −0.589, OR_{adj} = 0.555 [0.341–0.864], p_{adj} = 0.021) was related to decreased diabetes risk, while pasta intake of *everyday* (β_{adj} = 0.873, OR_{adj} = 2.394 [1.151–4.575], p_{adj} = 0.012) was related to increased diabetes risk.

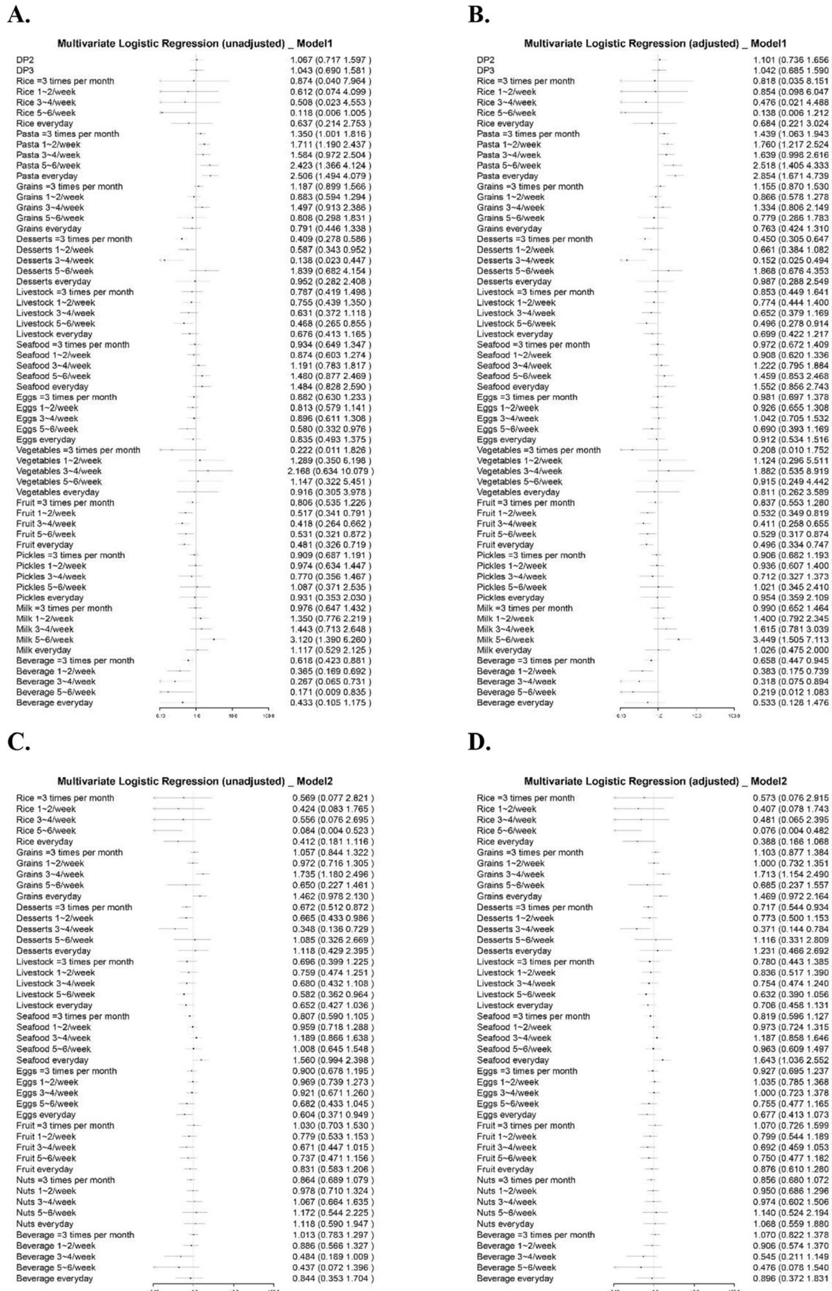

Fig. 2 Forest plots of multivariate logistic regression. **a** Model 1 without adjustment. **b** Model 1 after adjustment. **c** Model 2 without adjustment. **d** Model 2 after adjustment

Discussion

This study specific to the minority population in Southern China briefly reveals dietary habits of Guangxi Southern Chinese and the associations between food intake and diabetes risk, and provides new evidence for study in diabetes risk factors. Self-reported history of diabetes (model 1) could be referenced for research, and daily eating habit may be affected by the recognition of known disease states. The current Glu level (model 2) could contribute to diabetes discovery of persons with prediabetes, who retained the most common dietary habits. The baseline data could only provide blood Glu level without typical self-symptom description or retested Glu data; therefore, diabetes is difficult to diagnose [14]. However, random blood glucose is strongly associated with undiagnosed diabetes and a robust dose response [15].

Dietary control is necessary for diabetes prevention and treatment. The differences in the eating habits of various ethnicities make the division of DPs difficult [16–19]. People who adhere to *Balanced* (DP1) most probably obtain abundant and balanced nutrients. People with *Basic* (DP2) and *Insufficient* (DP3) may be prone to malnourished. In China, the intake of low-fat milk, fruit, vegetables, nuts, and seafood have increased moderately over time from 1991 to 2011, but the average intake of these foods was still below optimal levels in 2011 [20]. The simplified FFQ is difficult to determine the quantity but only frequency of food intake. However, overnutrition is difficult to define and needs to be defined according to specific nutrients. Determining what to eat and how to eat remains very challenging for many individuals with diabetes, and meal planning should be individualized as individuals have different nutrient requirements [21]. Many DPs could help people from developing diabetes [22, 23], under which the total consumption of carbohydrates or fats is reduced, and specific food categories and quality are not strictly regulated [24].

Higher frequency of fruit intake is protective factor for diabetes, which is consistent with the evidence all over the world [25–27]. Vitamin C and total carotenoids are the most consistently responsive biomarkers from fruits and vegetables in plasma, which can reduce the risk of developing T2DM [27]. Regular consumption of berries is suggested for T2DM prevention; the biological function of the extract is related to glucose metabolism [28]. Interestingly, we discovered a more frequent dessert consumption ($p_{\text{trend}} \leq 0.001$) has a higher diabetes risk, but a limited frequency of dessert and beverage consumption may be more protective to diabetes than no consumption, which is consistent with the Shanghai cohort [29]. But why small sugar content from desserts or beverage can reduce diabetes risk? A randomized controlled trial (RCT) indicated that sweet sugar beverages can modulate sugar metabolism and lipid metabolism [30]. Accordingly, low frequency of sweet intake from desserts or beverage may promote the secretion of insulin or regulate the concentrations of glucose-related substances.

The dietary habits of Southern Chinese are rice-based, and the frequency of rice intake among Southern Chinese people with different DPs was not substantially different. Daily pasta consumption is related to increased diabetes risk, especially in population over 60 years old. Pasta consumption within the limits recommended for total carbohydrate intake is not associated with poor glycemic control [31]. A RCT indicated substantially lower peak glucose levels in higher protein pasta group and regular pasta group compared with the white rice group, suggesting different food types with similar macronutrient content produce considerably different postprandial glycemic responses in diabetes patients [32].

According to Dietary Guidelines for Chinese Residents [33], the recommended daily milk and milk product intake is 300 g. However, the milk intake of Chinese people is usually insufficient, and the awareness rate about nutrition related to milk is worrying [34]. We found that milk intake of *5–6 times per week* increased diabetes risk in males and people under 60 years old. It puzzled us and the result is not in line with previous studies [35]. This difference may be caused by the geographical difference of the participants (Southern Chinese in Guangxi vs. Singapore-based Chinese).

Strengths and limitations

The strengths are large samples and specific populations from the representative minority areas. However, the limitations of the cohort field investigation, such as the long duration and imperfect condition of sample storage, may be unavoidable, which may cause a certain difference between detected and actual values. Converting Glu into binary data may help reduce error or bias. Besides, DPs may not be consistent with the standards introduced in the guideline. The simplified FFQ may be subject to measurement error and recall bias [36]. Future work in the follow-up process will try to improve the self-report instrument and include larger samples.

Conclusions

The DPs of Southern Chinese in Guangxi were related to food abundance and frequency of intake, which had no significant association with diabetes risk. Increased pasta and moderate amounts of grains, seafood, and milk were positively associated with diabetes risk, while increased fruit and moderate amounts of rice, desserts., livestock, eggs, and beverage were inversely associated with diabetes risk. Habitual fruit intake and moderate sweetness may be beneficial in diabetes management.

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Availability of data and material Not applicable

Code availability Not applicable

Author contribution Qiu X., Zeng X., Su L., Liu S., and Huang D.: designed the research; Ma X., Liu B., and Tang P.: collected the data and assisted with statistics; Guo X.: collected the data, analyzed the data and wrote the manuscript; Qiu X.: critically revised the manuscript; Liu S.: data management; Guo X. and Qiu X.: had primary responsibility for the final content; and all authors: read and approved the final manuscript.

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Declarations

Ethics approval This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Ethics Committee of Guangxi Medical University (No. 20170201-1).

Consent to participate Written informed consent was obtained from all subjects after they were briefed on the study.

Consent for publication Not applicable

Conflict of interest The authors declare no competing interests.

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