The relationship between proportions of carbohydrate and fat intake and hyperglycemia risk in Chinese adults

Yayun Fan [1], Qingqing Huang [2], Honglan Gao[1], Fengying Huang[3], Dingliu He[1, *]

[1] Department of Clinical Nutrition, Yancheng Clinical College of Xuzhou Medical University, The First People's Hospital of Yancheng, Yancheng, China.

[2] Department of Clinical Laboratory, The First Affiliated Hospital of Anhui Medical University, No. 218 Jixi Road, Hefei, 230032, Anhui, China.

[3] Department of Clinical Nutrition, Third Affiliated Hospital of Soochow University, No. 185 Juqian Road, Changzhou, China.

[*]**Correspondence should be addressed to:** Dingliu He, E-mail: hedingliu@163.com, Department of Clinical Nutrition, Yancheng Clinical College of Xuzhou Medical University, The First People's Hospital of Yancheng, Yancheng, 224001, P. R. China.

Running title: carbohydrate and fat intake and hyperglycemia

This is an Accepted Manuscript for Public Health Nutrition. This peer-reviewed article has been accepted for publication but not yet copyedited or typeset, and so may be subject to change during the production process. The article is considered published and may be cited using its DOI 10.1017/S1368980024001204

Author contributions: Y.F. and D.H. designed the research; Y.F., Q.H. and H.G. analyzed the data; Y.F., Q.H. and D.H. wrote the manuscript; Y.F., H.G., F.H. and D.H. revised the manuscript. All the authors approved the final version of the paper.

Acknowledgements: We thank the National Institute for Nutrition and Health, China Center for Disease Control and Prevention.

Funding: This research did not receive any specific grant from funding agencies.

Declaration of Competing Interests: No competing interests have been declared.

Ethical Standards Disclosure: 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 University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety, Chinese Center for Disease Control and Prevention.

Abstract

Objective: To address the relationship between the proportions of carbohydrates and fat and hyperglycemia in the Chinese population.

Design: A cross-section research involving data from the China Health and Nutrition Survey in 2009, and nutritional status and health indicators were mainly focused.

Setting: China

Participants: 8197 Chinese individuals aged over 16 years, including 1345 subjects had a low carbohydrate and high fat diet (LCHF), 3951 individuals had a medium proportion of carbohydrate and fat (MPCF) diet, 2660 participants had a high carbohydrate and low fat (HCLF) diet and 241 people had the very high carbohydrate and low fat (VHCLF) diet.

Results: Subjects with the HCLF diet were significantly associated with an increased risk of hyperglycemia (OR:1.142, 95%CI:1.022-1.276) when compared with the individuals with the MPCF diet. Meanwhile, people with a VHCLF diet had a higher risk of hyperglycemia (OR:1.829, 95%CI:1.377-2.429). In contrast, the association between participants with an LCHF diet and hyperglycemia was not significant (OR:1.082, 95%CI:0.942-1.243) with adjusting a series of confounding factors. Furthermore, people with a VHCLF diet were significantly associated with a higher risk of hyperglycemia in the major energy levels and social characteristics subgroup.

Conclusion: We found the HCLF and VHCLF diets were significantly associated with a high risk of hyperglycemia. And, the association between LCHF diets and the risk of hyperglycemia was not significant.

Keywords: China Health and Nutrition Survey (CHNS), proportions of carbohydrate and fat, hyperglycemia, high carbohydrate and low fat (HCLF), low carbohydrate and high fat (LCHF)

1. Introduction

In recent years, with changes in people's lifestyles and social progress, hyperglycemia has become a serious disease in the world. As a common metabolic abnormality disease, the prevalence of hyperglycemia in China was continually increased and ranked first in the world [1, 2]. Hyperglycemia is a well-known major factor of metabolic syndrome, which gives rise to a huge burden on the healthcare system[3]. Hence, several methods have been used to reduce the risk of hyperglycemia, such as exercise, lifestyle changes and dietary pattern improvement[4]. Moreover, medical nutrition therapy has become a focal treatment for hyperglycemia, which aims to find an optimal macronutrient composition and energy intake[5]. However, unstable protein ingestion is not recommended for subjects due to malnutrition or nephropathy[6]. For this reason, the macronutrient composition was always regulated by carbohydrates and fat. In China, the average proportions of carbohydrates and fat intake among adults were higher than in the Western populations, despite the carbohydrate intake has reduced in recent years[7, 8]. Several studies have reported that the proportions of carbohydrates and fat were associated with chronic disease[9, 10]. However, there is a lack of research on the correlation between this proportion and hyperglycemia. Therefore, we conducted this study and aimed to address the relationship between the proportions of carbohydrates and fat and hyperglycemia in the Chinese population.

2. Materials and methods

2.1 Study design and population

The China Health and Nutrition Survey (CHNS), an ongoing cohort research, provided the data that we used. The CHNS, which is a longitudinal research, tries to spot changes in geographic areas, public services, economic growth, nutritional status, and health indicators. Since the beginning of CHNS in 1989, the population has been monitored every two to four years. A sample of over 7200 homes, encompassing more than 30000 people in 15 provinces, was obtained. An earlier cohort profile explains in full the design and sampling procedures of CHNS [11].

The data we used were obtained in 2009. The data mainly contain dietary intake, blood indicators, physical measurements and lifestyle information. After excluding participants with missing dietary data, BMI, blood pressure and blood biomarker messages, implausibly low or high energy intake levels (<500 or >5000 kcal), abnormal proportions of energy from protein

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

(<5% or >20%), or age under 16 years, 8197 individuals were included in the final analysis. The participant selection process is described in Figure 1.

2.2 Dietary data collection

The dietary intake of participants was recorded by the trained interviewer, through a 3-day 24-hour recall method at the individual level, and a food inventory was performed at the household level over the same three-day period [12]. The household food consumption was calculated by measuring the changes in the inventory from the beginning to the end of the survey. The individual average total energy and nutrient intakes (carbohydrates, fats and proteins) were calculated based on the China food composition tables [13].

2.3 carbohydrate and fat proportion groups

When the ratio of protein intake is normal, a high level of carbohydrates is inevitably accompanied by a low level of fat, and vice versa. Therefore, we divided the subjects into four groups based on their proportion of carbohydrates: low carbohydrate and high fat group (LCHF), when the proportions of energy from carbohydrates < 45%; the medium proportion of carbohydrate and fat group (MPCF), 60%≥proportions of energy from carbohydrate≥45%; high carbohydrate and low fat group (HCLF), 75%>proportions of energy from carbohydrate>60%; and very high carbohydrate and low fat group (VHCLF), proportions of energy from carbohydrate≥75%.

2.4 Hyperglycemia

The blood samples of participants were collected and assayed in 2009, and follow-up blood data have not been made publically available. Blood samples were collected in three tubes, a total of 12 ml of blood for individuals greater than seven years old. Fasting blood glucose was measured through the GOD-PAP by Hitachi 7600 UK and tested in Beijing Central Laboratory, and glycated hemoglobin (HbA1c) was tested by hlc-723G7 USA in the provincial laboratory. In addition, subjects were asked to report their diabetes status and treatment ways. Thus, in our study, hyperglycemia was defined as glycated HbA1c≥5.7%, or fasting blood glucose≥6.1mmol/L, or self-reported diabetes, or taking any anti-hyperglycemic

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

therapy [14].

2.5 Other variables

The participants were divided into groups based on their alcohol-drinking status, tea-drinking and smoking status (Yes/No). Location was recorded as urban or rural. Overweight was defined as BMI≥24.0 kg/m^2, and subjects were divided into two levels (Yes/No)[15]. People aged below 45 years were defined as young, and we divided participants into two groups (Yes/No). The blood pressure was calculated by the mean of three measurements. Individuals were diagnosed with hypertension when DBP≥90 mmHg or SBP≥140 mmHg or self-reported hypertension or taking anti-hypertension drugs. Education was divided into four levels: none, primary school graduate, middle school graduate and a college degree, and a college degree was defined as high education level. Energy intake was divided into the following four levels: less than 1400, 1400~2000, 2000~2600kcal and more than 2600 kcal.

2.6 Statistical analysis

The data analysis software package SAS 9.4 (SAS Institute Inc., Cary, North Carolina, USA) was used for the data analysis. The mean and standard deviation (SD) are used to describe the continuous variables (e.g. age). When the data were normally distributed, we used ANOVA to detect the differences in the four groups. A chi-square test was used to detect the differences in sex, location, education levels, tea drinking, smoking, and hypertension. The multivariable logistic regression was used to calculate the odds ratio (OR) and 95% confidence interval (95% CI) of hyperglycemia in each group, and the MPCF diet intake group was used as the reference. The adjusted variables included age, BMI, gender, location, education, total energy, hypertension, smoking, alcohol drinking, and tea-drinking status. The significance level was set at 0.05 (two-sided).

3. Results

3.1 Characteristics of the participants

The characteristics of the study individuals are presented in Table 1. There were 8197 participants in this study, and the overall prevalence of hyperglycemia was 38.4%. Among the total participants, 1345 subjects had an LCHF diet, 3951 individuals had an MPCF diet, 2660 participants had an HCLF diet and 241 people had the VHCLF diet. Compared to individuals in

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

other groups, those with an LCHF diet were older and more likely to live in urban, be highly educated, have higher energy intake and included a greater proportion of subjects who drank alcohol, tea and smoked. Furthermore, the participants with a VHCLF diet were more likely to live in rural, be lowly educated, have a lower energy intake and include a smaller ratio of individuals who drank alcohol, tea and smoked.

3.2 Risk of hyperglycemia by different carbohydrate-fat proportions

The OR(95%CI) of the association between hyperglycemia and carbohydrate-fat proportion is summarized in Table 2. After adjusting for age, sex, BMI, location, energy, education alcohol, smoking, tea drinking and hypertension, subjects with the HCLF diet were significantly associated with an increased risk of hyperglycemia (OR:1.142, 95%CI:1.022-1.276), when compared with the individuals with the MPCF diet. Meanwhile, people with the VHCLF diet had a higher risk of hyperglycemia (OR:1.829, 95%CI:1.377-2.429). In contrast, the association between participants with an LCHF diet and hyperglycemia was reversed to not significant (OR:1.082, 95%CI:0.942-1.243), after adjusting a series above confounding factors.

3.3 *Influence of different energy intake levels on the association between carbohydrate-fat proportion and hyperglycemia*

After adjusting for age, sex, BMI, location, education alcohol, smoking, tea drinking and hypertension, we estimated the associations of carbohydrate-fat proportion with hyperglycemia at different energy intake levels. As shown in Table 3, when compared with the individuals with an MPCF diet, those with the HCLF diet had a higher risk of hyperglycemia in the low energy intake level (OR:1.427, 95%CI:1.029-1.981). Furthermore, people with a VHCLF diet had a higher risk of hyperglycemia in the low and middle energy intake levels, the OR(95%CI) was 2.152(1.153-4.020), 1.795(1.111-2.901) and 2.068(1.231-3.472), respectively. Meanwhile, we have not observed these significant associations in the high energy intake level.

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

3.4 *Subgroup analyses of the association between carbohydrate-fat proportion and hyperglycemia*

We further evaluated the associations of carbohydrate-fat proportion with hyperglycemia in each subgroup. As shown in Figure 2, the participants who intake an HCLF and VHCLF diets were significantly associated with a high risk of hyperglycemia in the most of subgroups, when compared with those who had an MPCF diet, especially the people who were living in rural (OR:1.138, 95%CI:1.003-1.292 and OR:2.018, 95%CI:1.482-2.746, respectively).

4. Discussion

By using data from a nationally, large sample size cross-sectional cohort in China, we observed that there was a significant association between the proportion of carbohydrate-fat intake and hyperglycemia in adults. In detail, the individuals with an HCLF and VHCLF diet were significantly associated with a higher risk of hyperglycemia. Furthermore, people with a VHCLF diet were significantly associated with a higher risk of hyperglycemia in the major energy levels and social characteristics subgroup.

To the best of our knowledge, this is the first study to explore the association of different proportions of carbohydrate-fat intake with hyperglycemia among nationally representative Chinese adults. To date, lots of studies have investigated the association between the different proportions of carbohydrate-fat intake and the risk of diabetes and cardiovascular diseases[16-18]. However, there are no consistent conclusions based on these associations. For instance, one research demonstrated that a high fat and low carbohydrate diet score was associated with the high incidence of type 2 diabetes in the Chinese population[18]. On the contrary, another study in Japan indicated that a Low carbohydrate diet was associated with a decreased risk of type 2 diabetes in women[17]. Additionally, two studies about the Hawaii diet and Okinawa diet models described that the highly complex carbohydrate diet and a healthy fat profile can decrease the risk of cardiovascular disease and blood glucose values[19, 20]. Nevertheless, it is unclear whether the effect of these special diet models on people is due to the proportions of carbohydrates and fats or their mineral content. And Chinese people always intake refined cereals as their staple food which may be different from the carbohydrates in this research. In our study, individuals with an HCLF and VHCLF diet were significantly associated with a

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

higher risk of hyperglycemia. It was consistent with one previous animal experiment, which presented that a high carbohydrate diet intake can increase postprandial glycemia in healthy cats when compared with diets high in fat or protein[21]. Meanwhile, we found there was no significant association between the LCHF diet and hyperglycemia in our study. Similarly, one research that included 1018 pregnant women shows these associations were not significant after adjustment for covariates[22]. In the past, the LCHF diet was usually used for weight loss and treatment of epilepsy, though there is a lack of data supporting long-term efficacy and safety[23].

Not only that, we explored these associations in various energy intake levers. We found that people with the HCLF and VHCLF diet had a higher risk of hyperglycemia in the low and middle energy intake levels and these associations were not significant in the highest energy levels. Our results indicated that when the total energy intake was appropriate people need to decrease the proportions of carbohydrate-fat, which may be conducive to reducing the risk of hyperglycemia. Moreover, our results also show that the participants who intake an HCLF and VHCLF diets were significantly associated with a high risk of hyperglycemia in the majority of subgroups, especially those who live in rural. One previous survey reported that people who live in rural areas have a higher prevalence and lower awareness rate about hyperglycemia[24]. Meanwhile, rural dwellers may lack sufficient health knowledge and medical support, which also could strengthen the associations between the different proportions of carbohydrate-fat intake and the risk of hyperglycemia.

Currently, the underlying mechanisms have not been clearly elucidated, and several possible illustrations have been proposed. First, the most of carbohydrates in HCLF diets in China were composed of refined grain which has a high glycemic index. However, high glycemic index foods can elicit higher glycaemic and insulinemic responses and promote insulin resistance through β-cell exhaustion[25]. Meanwhile, insulin resistance can increase the risk of adverse cardiovascular events, then these factors further interact and increase the levels of blood glucose[26]. Second, the HCLF diet could upregulate the markers of inflammation and oxidative stress by generating reactive oxygen species through several pathways, which also lead to insulin and impaired insulin secretion [27, 28]. Third, a previous study reported that people who took an HCLF diet had lower levels of serum total adiponectin[29]. Nevertheless,

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

the lack of adiponectin could contribute to glucose intolerance and hyperglycemia[30]. In turn, abundant adiponectin can reduce the burden of liver ceramide and improve the effect of hepatic insulin[31]. We think these illustrations may explain how an HCLF diet affects hyperglycemia.

The strengths of this study include the large sample size of participants in the real world. Furthermore, we first clearly show the association between the different proportions of carbohydrates and fat and hyperglycemia. We found that individuals who intake an HCLF and VHCLF diet were significantly associated with a higher risk of hyperglycemia. However, limitations also exist in this study. First, we calculated the individual intake of oil based on consumption only at home, which may cause an underestimation of the intake of fat. Second, we did not differentiate between different types of carbohydrates and fats, which may have unique effects on hyperglycemia. Third, we cannot eliminate all unmeasured or residual confounding factors, which may affect the associations observed in this study, even though we have adjusted for many confounders in the analysis step.

5. conclusion

In conclusion, our study indicated that people with the HCLF and VHCLF diets were significantly associated with a higher risk of hyperglycemia. And these results could help people comprehend their dietary structure and adjust appropriately to prevent and treat hyperglycemia.

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

Reference

1. International Diabetes Federation (2021) IDF Diabetes Atlas, 10th edn. https://www.diabetesatlas.org
2. Li Y, Teng D, Shi X *et al.* (2020) Prevalence of diabetes recorded in mainland China using 2018 diagnostic criteria from the American Diabetes Association: national cross sectional study. *BMJ (Clinical research ed)* 369, m997.
3. (2020) Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet (London, England)* 396, 1223-1249.
4. Samson SL & Garber AJ (2014) Metabolic syndrome. *Endocrinology and metabolism clinics of North America* 43, 1-23.
5. Vitale M, Masulli M, Rivellese AA *et al.* (2016) Influence of dietary fat and carbohydrates proportions on plasma lipids, glucose control and low-grade inflammation in patients with type 2 diabetes-The TOSCA.IT Study. *European journal of nutrition* 55, 1645-1651.
6. Tantisattamo E, Dafoe DC, Reddy UG *et al.* (2019) Current Management of Patients With Acquired Solitary Kidney. *Kidney international reports* 4, 1205-1218.
7. Su C, Zhao J, Wu Y *et al.* (2017) Temporal Trends in Dietary Macronutrient Intakes among Adults in Rural China from 1991 to 2011: Findings from the CHNS. *Nutrients* 9.
8. Heidari Z, Feizi A, Azadbakht L *et al.* (2019) Usual energy and macronutrient intakes in a large sample of Iranian middle-aged and elderly populations. *Nutrition & dietetics: the journal of the Dietitians Association of Australia* 76, 174-183.
9. Kwon YJ, Lee HS Lee JW (2018) Association of carbohydrate and fat intake with metabolic syndrome. *Clinical nutrition (Edinburgh, Scotland)* 37, 746-751.
10. He D, Sun N, Xiong S *et al.* (2021) Association between the proportions of carbohydrate and fat intake and hypertension risk: findings from the China Health and Nutrition Survey. *Journal of hypertension* 39, 1386-1392.

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

11. Zhang B, Zhai FY, Du SF *et al.* (2014) The China Health and Nutrition Survey, 1989-2011. *Obesity reviews : an official journal of the International Association for the Study of Obesity* 15 Suppl 1, 2-7.

12. He D, Qiao Y, Xiong S *et al.* (2020) Association between Dietary Quality and Prediabetes based on the Diet Balance Index. *Scientific reports* 10, 3190.

13. Yang Y (2018) *China food composition tables.* beijing: Peking University Medical Press.

14. Kocher T, König J, Borgnakke WS *et al.* (2018) Periodontal complications of hyperglycemia/diabetes mellitus: Epidemiologic complexity and clinical challenge. *Periodontology 2000* 78, 59-97.

15. Chen H, Zhang R, Zheng Q *et al.* (2018) Impact of body mass index on long-term blood pressure variability: a cross-sectional study in a cohort of Chinese adults. *BMC public health* 18, 1193.

16. Dietary Guidelines Advisory Committee DPS (2020) USDA Nutrition Evidence Systematic Reviews. In *Dietary Patterns and Risk of Cardiovascular Disease: A Systematic Review*. Alexandria (VA): USDA Nutrition Evidence Systematic Review.

17. Nanri A, Mizoue T, Kurotani K *et al.* (2015) Low-carbohydrate diet and type 2 diabetes risk in Japanese men and women: the Japan Public Health Center-Based Prospective Study. *PloS one* 10, e0118377.

18. He YN, Feskens E, Li YP *et al.* (2012) Association between high fat-low carbohydrate diet score and newly diagnosed type 2 diabetes in Chinese population. *Biomedical and environmental sciences : BES* 25, 373-382.

19. Shintani TT, Beckham S, Brown AC *et al.* (2001) The Hawaii Diet: ad libitum high carbohydrate, low fat multi-cultural diet for the reduction of chronic disease risk factors: obesity, hypertension, hypercholesterolemia, and hyperglycemia. *Hawaii medical journal* 60, 69-73.

20. Willcox DC, Scapagnini G Willcox BJ (2014) Healthy aging diets other than the Mediterranean: a focus on the Okinawan diet. *Mechanisms of ageing and development* 136-137, 148-162.

21. Farrow HA, Rand JS, Morton JM *et al.* (2013) Effect of dietary carbohydrate, fat, and protein on postprandial glycemia and energy intake in cats. *Journal of veterinary internal medicine* 27, 1121-1135.

22. Chen Q, Chen Y, Wu W *et al.* (2021) Low-carbohydrate diet and maternal glucose metabolism in Chinese pregnant women. *The British journal of nutrition* 126, 392-400.

23. Paoli A, Rubini A, Volek JS *et al.* (2013) Beyond weight loss: a review of the therapeutic uses of very-low-carbohydrate (ketogenic) diets. *European journal of clinical nutrition* 67, 789-796.

24. Zhang FL, Xing YQ, Guo ZN *et al.* (2018) Prevalence and risk factors for diabetes and impaired fasting glucose in Northeast China: Results from the 2016 China National Stroke Screening Survey. *Diabetes research and clinical practice* 144, 302-313.

25. Mohan V, Unnikrishnan R, Shobana S *et al.* (2018) Are excess carbohydrates the main link to diabetes & its complications in Asians? *The Indian journal of medical research* 148, 531-538.

26. Laakso M & Kuusisto J (2014) Insulin resistance and hyperglycaemia in cardiovascular disease development. *Nature reviews Endocrinology* 10, 293-302.

27. Luc K, Schramm-Luc A, Guzik TJ *et al.* (2019) Oxidative stress and inflammatory markers in prediabetes and diabetes. *Journal of physiology and pharmacology : an official journal of the Polish Physiological Society* 70.

28. Barrea L, Marzullo P, Muscogiuri G *et al.* (2018) Source and amount of carbohydrate in the diet and inflammation in women with polycystic ovary syndrome. *Nutrition research reviews* 31, 291-301.

29. Ruth MR, Port AM, Shah M *et al.* (2013) Consuming a hypocaloric high fat low carbohydrate diet for 12 weeks lowers C-reactive protein, and raises serum adiponectin and high density lipoprotein-cholesterol in obese subjects. *Metabolism: clinical and experimental* 62, 1779-1787.

30. Moyce Gruber BL, Cole LK, Xiang B *et al.* (2022) Adiponectin deficiency induces hepatic steatosis during pregnancy and gestational diabetes in mice. *Diabetologia* 65, 733-747.

31. Tao C, Sifuentes A Holland WL (2014) Regulation of glucose and lipid homeostasis by adiponectin: effects on hepatocytes, pancreatic β cells and adipocytes. *Best practice & research Clinical endocrinology & metabolism* 28, 43-58.

Table 1. Baseline characteristics of the individuals in the four carbohydrate-fat proportion groups

Factor	LCHF	MPCF	HCLF	VHCLF	*P*
Subjects (n,%)	1345 (16.4)	3951(48.2)	2660(32.5)	241(2.9)	
Female (n,%)	677(50.3)	2148(54.4)	1413(53.1)	133(55.2)	0.074
Age (years)	51.9±15.5	49.9±15.3	49.2±15.2	50.0±14.9	0.001
Urban (n,%)	749(55.7)	1304(33.0)	553(20.8)	38(15.8)	0.001
High-level education (n,%)	221(16.4)	545(13.8)	187(7.0)	12(5.0)	0.001
BMI (kg/m^2)	23.6±3.5	23.3±3.5	23.1±3.5	23.5±3.4	0.001
Energy (Kcal)	2195.0±646.6	2146.6±614.6	2083.6±619.6	1870.6±611.3	0.001
SBP (mmHg)	125.5±19.2	124.8±19.0	124.3±19.5	123.9±18.0	0.223
DBP (mmHg)	80.2±11.3	80.7±11.4	80.4±11.6	80.1±11.0	0.555
HbA1c (%)	5.7±1.0	5.6±0.9	5.6±1.0	5.7±0.8	0.005
Hypertension (n,%)	436(32.4)	1227(31.1)	769(28.9)	72(29.9)	0.106
Hyperglycemia (n,%)	551(50.0)	1460(37.0)	1014(38.1)	119(49.4)	0.001
Smoked (n,%)	454(33.8)	1169(29.6)	831(31.2)	65(27.0)	0.018
Tea (n,%)	647(48.1)	1412(35.7)	749(28.2)	50(20.8)	0.001
Alcohol (n,%)	531(39.5)	1278(32.4)	798(30.0)	51(21.2)	0.001

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

Table 2. Odds ratio (95% confidence interval) of the association between hyperglycemia and carbohydrate-fat proportion

	Groups			
	LCHF	MPCF	HCLF	VHCLF
Model 1	1.184(1.043,1.344)	1	1.051(0.950,1.163)	1.664(1.282,2.160)
Model 2	1.067(0.931,1.222)	1	1.131(1.015,1.261)	1.774(1.341,2.346)
Model 3	1.083(0.943,1.244)	1	1.137(1.018,1.270)	1.805(1.361,2.395)
Model 4	1.082(0.942,1.243)	1	1.142(1.022,1.276)	1.829(1.377,2.429)

Model 1 adjusted no variable.

Model 2 adjusted age, sex and BMI.

Model 3 adjusted age, sex, BMI, location, energy and education.

Model 4 adjusted age, sex, BMI, location, energy, education, alcohol, smoking, tea drinking and hypertension.

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

Table 3. Odds ratio (95% confidence interval) of the association between carbohydrate-fat proportion and hyperglycemia in different energy levels

Energy levels	Groups			
(kcal)	LCHF	MPCF	HCLF	VHCLF
E<1400	1.247(0.798,1.950)	1	1.427(1.029,1.981)	2.152(1.153,4.020)
2000>E≥1400	1.168(0.908,1.503)	1	1.130(0.932,1.370)	1.795(1.111,2.901)
2600>E≥2000	0.943(0.745,1.195)	1	1.056(0.872,1.278)	2.068(1.231,3.472)
E>2600	1.143(0.862,1.514)	1	1.176(0.924,1.497)	1.343(0.609,2.963)

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

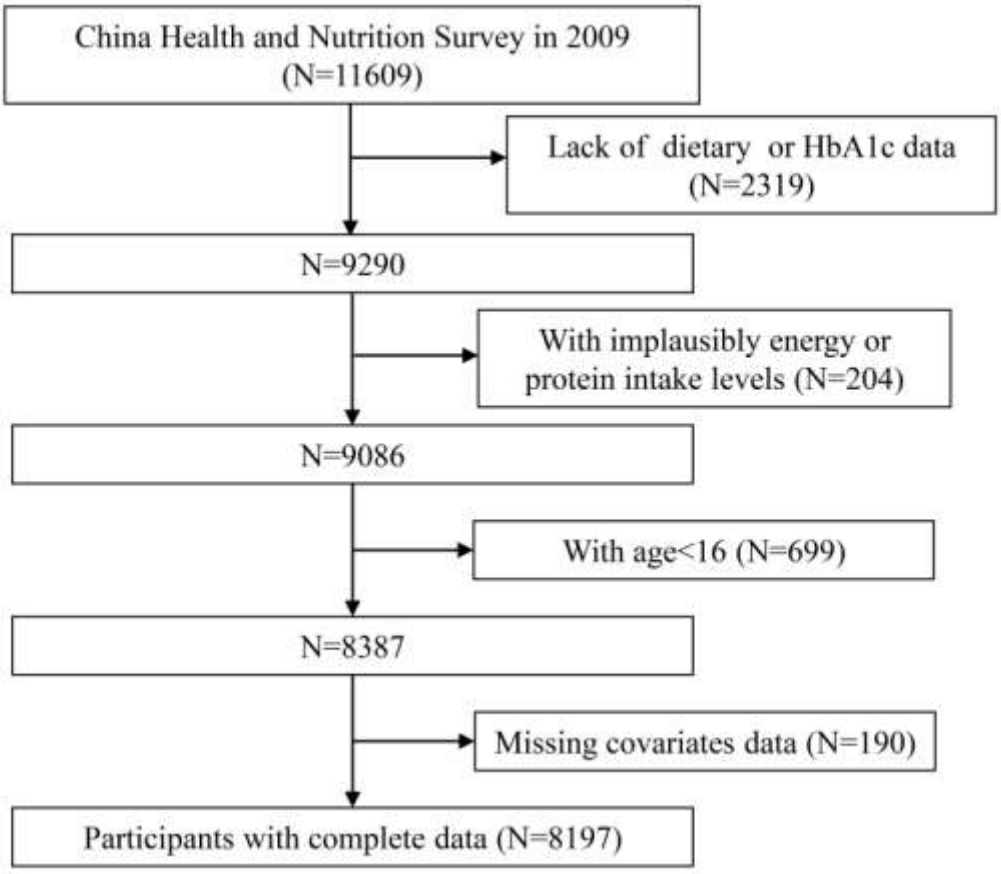

Figure 1 Flow chart of the sample selection methods in each step

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press

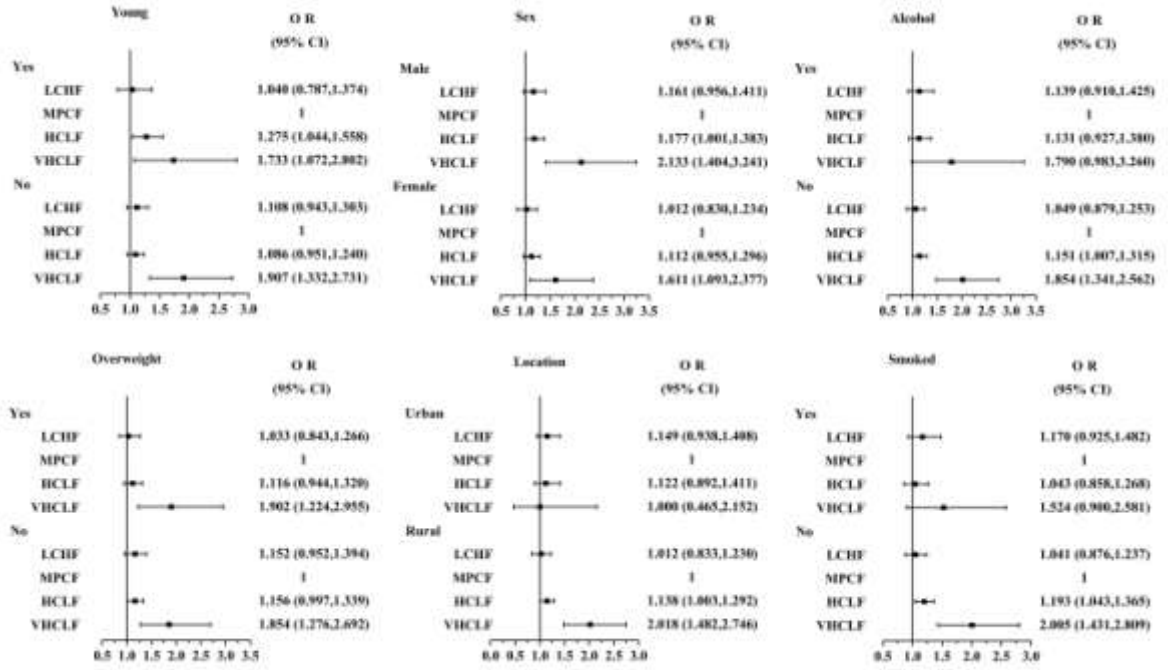

Figure 2 subgroup analyses of the association between carbohydrate-fat proportion and hyperglycemia

https://doi.org/10.1017/S1368980024001204 Published online by Cambridge University Press