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Original Article

Association between carbohydrate-to-fiber ratio and the risk of periodontitis

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KEYWORDS
Carbohydrate;
Fiber;
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Periodontitis

Abstract *Background/purpose:* Periodontitis is a chronic multifactorial inflammatory disease with dental plaque accumulation. This study aimed to analyze the association between carbohydrate-to-fiber ratio and periodontitis risk.
Materials and methods: In this cross-sectional study, the data of 6470 participants aged ≥30 years with available oral health exam data of periodontal status were collected from NHANES 2009–2014. Participants were divided into no & mild periodontitis group (n = 3309) and moderate & severe periodontitis group (n = 3161). The possible correlation between the carbohydrate-to-fiber ratio and the risk of periodontitis was explored via univariate and multivariable logistic regression analyses. Odds ratio (OR) and 95% confidence interval (CI) were applied as the effect size.
Results: After adjusting for all the confounding factors, carbohydrate-to-fiber ratio <10.89 (OR = 0.82, 95% CI: 0.69–0.97), carbohydrate-to-fiber ratio of 10.89–14.02 (OR = 0.74, 95% CI: 0.63–0.87), carbohydrate-to-fiber ratio of 14.03–18.47 (OR = 0.83, 95% CI: 0.71–0.97) were correlated with reduced risk of periodontitis. In people aged ≥65 years, carbohydrate-to-fiber ratio of 10.89–14.02 (OR = 0.54, 95% CI: 0.30–0.95) and carbohydrate-to-fiber ratio of 14.03–18.47 (OR = 0.56, 95% CI: 0.37–0.86) were correlated with reduced risk of periodontitis in comparison with carbohydrate-to-fiber ratio ≥18.48 group. The decreased risk of periodontitis was also found in males with carbohydrate-to-fiber ratio of 10.89–14.02 (OR = 0.69, 95% CI: 0.49–0.97) and carbohydrate-to-fiber ratio of 14.03–18.47 (OR = 0.73, 95% CI: 0.56–0.95). In people without diabetes, we found that those with carbohydrate-to-fiber ratio <10.89 (OR = 0.75, 95% CI: 0.61–0.93), carbohydrate-to-fiber ratio of 10.89–14.02 (OR = 0.68, 95% CI: 0.53–0.88) and carbohydrate-to-fiber ratio of 14.03–18.47 (OR = 0.84, 95% CI: 0.70–0.99) were linked with lower risk of periodontitis.

Abbreviations: OR, Odds ratio; CI, Confidence interval; NHANES, National Health and Nutrition Examination Surveys; HbA1c, Hemoglobin A1c; GED, General equivalent diploma; PIR, Ratio of family income to poverty; BMI, Body mass index; CDC, Centers for Disease Control; AL, Attachment loss; PD, Probing depth; SE, Standard error; SCFAs, Short Chain Fatty Acids; IL, Interleukin; TNF, Tumor necrosis factor; IFN, Interferon.

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Conclusion: Low carbohydrate-to-fiber ratio was associated with decreased risk of periodontitis.

Introduction

Periodontitis is a chronic multifactorial inflammatory disease with dental plaque accumulation, which is characterized by progressive destruction of the teeth-supporting apparatus, including the periodontal ligament and alveolar bone.[1] Periodontal has become the sixth most prevalent osteolytic disease in humans.[2] Periodontal is one of the most important public health problems all over the world, with 1.1 billion people suffering from severe periodontitis worldwide in 2019.[3] Patients with periodontitis were associated with increased risk of tooth loss and chewing dysfunction, which has a negative impact on their quality of life.[4] Periodontitis was reported to be associated with the risk of some other diseases including diabetes mellitus, kidney disease, premature birth, aspiration pneumonia, and arteriosclerosis.[5] To identify more factors associated with the risk of periodontitis was of great value for the management of this disease.

In recent years, the relationship between diet and periodontitis has received extensive attention.[6] As one of the most important components of diet, carbohydrate especially added sugar and dietary fiber intake was reported to be associated with the risk of periodontitis.[7] Studies have shown that higher consumption of sugars were associated with increased risk of periodontal disease.[8] Nielsen et al. indicated that low intake of whole grains and dietary fiber is a risk factor for periodontal disease/periodontitis.[9] These studies only focused on carbohydrate such as added sugar or dietary fiber intake, which might not represent the dietary carbohydrate quality. Recently, the carbohydrate-to-fiber ratio was proposed as a new indicator of dietary carbohydrate quality, which more completely reflected the quality of one's diet.[10] Carbohydrate-to-fiber ratio has been reported to be an important indicator of depressive symptoms, metabolic syndrome in patients with type 2 diabetes and cardiometabolic risk.[10–12] At present, there was no study investigated the relationship between carbohydrate-to-fiber ratio and the risk of periodontitis.

This study aims to investigate the relationship between carbohydrate-to-fiber ratio and the risk of periodontitis based on the data from the National Health and Nutrition Examination Surveys (NHANES) database. Subgroup analysis was performed stratifying age, gender, and complication of diabetes. The findings might provide reference for the prevention and treatment of periodontitis in the future.

Materials and methods

Study design and population

In this cross-sectional study, the data of 10,714 participants aged ≥30 years with available oral health exam data of periodontal status were collected from NHANES 2009–2014. NHANES is a nationwide survey conducted every year to collect health and diet information from a representative, non-institutionalized population in US. NHANES combines interviews, physical examinations, and laboratory evaluations to obtain a large amount of quantitative and qualitative data.[13] All participants provided a written informed consent prior to any data collection. Household questionnaires, telephone interviews, and examinations conducted by healthcare professionals and trained personnel were utilized to collect data. In the present study, subjects who had <2 teeth, incomplete information of 24 h dietary recall, no data on hemoglobin A1c (HbA1c), and reported an implausible energy intake (<500 or >3500 kcal/day for women and <800 or >4000 kcal/day for men) were excluded.[14,15] Finally, 6470 participants were involved in.

Potential confounders and definitions

Potential confounders in the present study included age (years), gender, race/ethnicity (Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black or other Race-including multi-racial), education [less than 9th Grade, 9–11th Grade, high school Grade/general equivalent diploma (GED) or equivalent, some college or AA degree, or college graduate or above], ratio of family income to poverty (PIR), smoking (never, former smoker or current smoker), drinking (<1 time/week, 1–7 times/week, or ≥8 times/week), physical activity (no or yes), body mass index (BMI) (thin, normal, overweight or fat), energy (kcal), diabetes (no or yes), dyslipidemia (no or yes), tooth lost (no or yes), and antifungal drug and antibiotics (no or yes).

Never smoking was defined based on the answer of "No" in SMQ020 (Smoked 100 cigarettes at further in life no smoking now before). Former smoker was defined based the answer of "No" in SMQ020 (Smoked 100 cigarettes at further in life no smoking now before) and SMQ040 (Do you now smoke cigarettes) and current smoker was defined based on the answer of "Yes" in SMQ0400 (Do you now smoke cigarettes). Physical activity was defined based on the average time of daily moderate-intensity physical activity + high-intensity physical activity × MET (PAD615 × 8.0 + PAD660 × 8.0 + PAD630 × 4.0 + PAD675 × 4.0 + PAD645 × 4.0). Diabetes was diagnosed based on glycosylated hemoglobin (≥6.5%), fasting blood glucose (≥126 mg/dL), OGTT-2h (≥200 mg/dL), or self-reported diabetes or anti-diabetic agents. Dyslipidemia was defined based on total cholesterol ≥ 200 mg/dL (5.2 mmol/L), triglyceride ≥ 150 mg/dL (1.7 mmol/L), low-density lipoprotein ≥ 130 mg/dL (3.4 mmol/L), high-density lipoprotein ≤ 40 mg/dL (1.0 mmol/L), self-reported hypercholesterolemia (BPQ060, BPQ080) or receiving lipid-lowering therapy.

Main variables and outcome variable

Carbohydrate-to-fiber ratio was the main variable in this study, which was calculated based on the average value of the sum of the dietary and supplement intake on the first day and the sum of the dietary and supplement intake on the second day. Among them DR1TCARB, and DR2TCARB were the dietary intake of carbohydrates in the two days, DS1TCARB, and DS2TCARB were the supplement intake of carbohydrates in the two days. DR1TFIBE and DR2TFIBE were dietary fiber intake in two days while DS1TFIBE and DS2TFIBE were dietary fiber supplement intake in two days. Carbohydrate-to-fiber ratio was diving the mean value of the intake of carbohydrate of the two days by the mean value of intake of dietary fiber of the two days. Due to the lack of reliable reference for the cut-off value of carbohydrate-to-fiber ratio, it was divided into four levels by quartile [Q_1 (0—10.88), Q_2 (10.89—14.02), Q_3 (14.03—18.47) and Q_4 ($\geq$18.48).

Periodontitis was defined based on the suggested the Centers for Disease Control and Prevention (CDC)/American Academy of Periodontology case definitions for surveillance of periodontitis.[16] Severe periodontitis was defined as having $\geq$2 interproximal sites with $\geq$6 mm of attachment loss (AL) and (not on the same tooth) and $\geq$1 interproximal site with $\geq$5 mm of probing depth (PD). Moderate periodontitis was defined as $\geq$2 interproximal sites with $\geq$4 mm of clinical AL (not on the same tooth) or $\geq$2 interproximal sites with PD $\geq$ 5 mm, also not on the same tooth. Mild periodontitis was defined as $\geq$2 interproximal sites with $\geq$3 mm of AL and $\geq$2 interproximal sites with $\geq$4 mm of PD or 1 site with $\geq$5 mm (not on the same tooth). For regression analyses using logistic models, severe and moderate periodontitis were compared with mild and none.

Statistical analysis

Measurement data were described as Mean (S.E), and comparison between two groups was performed by t-test. Enumeration data were described as the number of cases and constituent ratio [n (%)], and comparison between groups was performed by χ^2 test or Fisher's exact probability method. WTMEC2YR, SDMVPSU, and WTDR2D were used as weighted variables. The possible correlation between the carbohydrate-to-fiber ratio and the risk of periodontitis was explored via univariate and multivariable logistic regression analyses. In the multivariate logistic regression model 2, confounding factors of demographic variable including age, gender, race, education level and PIR were adjusted. In the multivariate logistic regression model 3, confounding factors including age, gender, race, education Level, PIR, smoking, drinking, physical activity, diabetes, tooth lost, and energy were adjusted. Sensitivity analysis was performed to compare the results in the multivariate logistic regression analysis using the data before and after the manipulation of the missing data. Subgroup analyses were stratified by age, sex, and diabetes to explore the association between carbohydrate-to-fiber ratio and risk of periodontitis in specific populations. Odds ratio (OR) and 95% confidence interval (CI) were applied as the effect size. Confidence level value was set as 0.05. SAS 9.4 software (SAS Institute Inc., Cary, NC, USA) was used for data extraction, data cleaning, statistical analysis and table output, and R Studio version 4.2.1 (2022-06-23) was used for drawing the forest plot.

Results

Comparisons of characteristics between people with no & mild periodontitis and people with moderate & severe periodontitis

In total, we found 10,714 participants aged $\geq$30 years with available oral health exam data of periodontal status from NHANES 2009—2014. Among them, subjects with <2 teeth (n = 12), incomplete information of 24 h dietary recall (n = 3624), no data on HbA1c (n = 183), women with energy <500 or >3500 kcal/day (n = 304) and men with energy <800 or >4000 kcal/day (n = 120) were excluded. Finally, 6470 participants were included. The screen process of participants was shown in Fig. 1. Participants were divided into no & mild periodontitis group (n = 3309) and moderate & severe periodontitis group (n = 3161).

The mean age of participants in the moderate & severe periodontitis group was higher than the no & mild periodontitis group (55.49 years vs 47.50 years). Education level was statistically different between the moderate & severe periodontitis group and the no & mild periodontitis group. The mean PIR in the moderate & severe periodontitis group was lower than the no & mild periodontitis group (2.86 vs 3.46). The carbohydrate intake in the moderate & severe periodontitis group was higher than the no & mild periodontitis group (122.01 gm/1000 kcal vs 119.47 gm/1000 kcal). Carbohydrate-to-fiber ratio in the moderate & severe periodontitis group was lower than the no & mild periodontitis group (16.43 vs 15.38). The percentages of subjects with tooth lost in the moderate & severe periodontitis group was higher than the no & mild periodontitis group (76.82% vs 49.49%) (Table 1).

Association between carbohydrate-to-fiber ratio and the risk of periodontitis

All the variables with statistical difference between the moderate & severe periodontitis group and the no & mild periodontitis group were confounding factors for the association between carbohydrate-to-fiber ratio and the risk of periodontitis (Table 1). As exhibited in Table 2, compared with those with carbohydrate-to-fiber ratio $\geq$18.48, those with carbohydrate-to-fiber ratio <10.89 (OR = 0.69, 95% CI: 0.59—0.82), carbohydrate-to-fiber ratio of 10.89—14.02 (OR = 0.72, 95% CI: 0.61—0.85), carbohydrate-to-fiber ratio of 14.03—18.47 (OR = 0.77, 95% CI: 0.65—0.90) might be associated with decreased risk of periodontitis in the unadjusted Model 1. After adjusted for demographic variables including age, gender, race, education level and PIR, carbohydrate-to-fiber ratio <10.89 (OR = 0.72, 95% CI: 0.60—0.85), carbohydrate-to-fiber ratio of 10.89—14.02 (OR = 0.66, 95% CI: 0.57—0.77), carbohydrate-to-fiber ratio of 14.03—18.47 (OR = 0.77, 95% CI: 0.65—0.91) might be associated with decreased risk of periodontitis. After

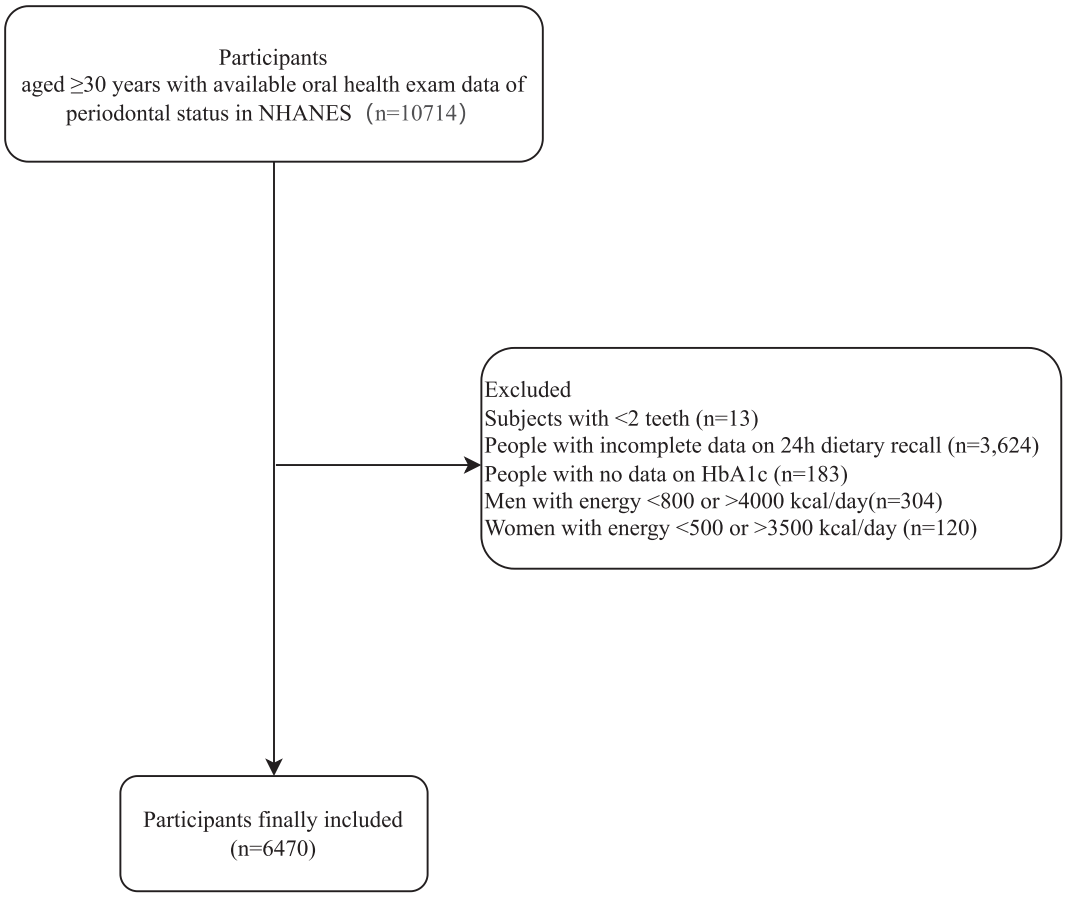

Figure 1 The screen process of participants.

adjusting for all the confounding factors including age, gender, race, education level, PIR, smoking, drinking, physical activity, diabetes, tooth lost and energy, carbohydrate-to-fiber ratio <10.89 (OR = 0.82, 95% CI: 0.69–0.97), carbohydrate-to-fiber ratio of 10.89–14.02 (OR = 0.74, 95% CI: 0.63–0.87), carbohydrate-to-fiber ratio of 14.03–18.47 (OR = 0.83, 95% CI: 0.71–0.97) were correlated with reduced risk of periodontitis.

Association between carbohydrate-to-fiber ratio and the risk of periodontitis in different subgroups

In people aged ≥65 years, carbohydrate-to-fiber ratio of 10.89–14.02 (OR = 0.54, 95% CI: 0.30–0.95) and carbohydrate-to-fiber ratio of 14.03–18.47 (OR = 0.56, 95% CI: 0.37–0.86) were correlated with reduced risk of periodontitis in comparison with carbohydrate-to-fiber ratio ≥18.48 group. The decreased risk of periodontitis was also found in males with carbohydrate-to-fiber ratio of 10.89–14.02 (OR = 0.69, 95% CI: 0.49–0.97) and carbohydrate-to-fiber ratio of 14.03–18.47 (OR = 0.73, 95% CI: 0.56–0.95). In people without diabetes, we found that those with carbohydrate-to-fiber ratio <10.89 (OR = 0.75, 95% CI: 0.61–0.93), carbohydrate-to-fiber ratio of 10.89–14.02 (OR = 0.68, 95% CI: 0.53–0.88) and carbohydrate-to-fiber ratio of 14.03–18.47 (OR = 0.84, 95% CI: 0.70–0.99) were linked with lower risk of periodontitis (Fig. 2).

Discussion

The present study evaluated the association between carbohydrate-to-fiber ratio and the risk of periodontitis based on the data from the NHANES database, the results delineated that carbohydrate-to-fiber ratio <18.48 was associated with decreased risk of periodontitis. Subgroup analysis depicted that decreased risk of periodontitis was identified in people aged ≥65 years or males with carbohydrate-to-fiber ratio of 10.89–18.47. In people without diabetes, carbohydrate-to-fiber ratio <18.48 were linked with reduced risk of periodontitis. The findings of the present study might provide a reference in encouraging people to improve their dietary carbohydrate quality, especially fiber intake for the management of periodontitis.

Carbohydrate-to-fiber ratio is an index for evaluating the dietary carbohydrate quality in people. A higher carbohydrate-to-fiber ratio may suggest an increased intake of processed or refined foods, while a lower ratio may indicate a diet of more whole or unprocessed foods.[12] Previously, dietary fiber intake was reported to be negatively correlated with periodontal disease in USA population.[9] Another study unveiled that patients with periodontitis have a reduced intake of fiber intake compared with healthy subjects.[17] Li et al. found that people with a daily diet that low in carbohydrates and rich in fiber had a protective effect on periodontitis.[18] These findings might provide evidence to the results in our study,

Table 1 Comparisons of characteristics between people with no & mild periodontitis and people with moderate & severe periodontitis.

Variables	Total (n = 6470)	Periodontitis		Statistics	*P*
		No or mild (n = 3161)	Moderate or severe (n = 3309)		
Age at diagnose, years, Mean (S.E)	51.07 (0.27)	47.50 (0.40)	55.49 (0.41)	t = −11.96	<0.001
Gender, n (%)				χ^2 = 38.963	<0.001
Male	3028 (47.12)	1178 (40.81)	1850 (54.97)		
Female	3442 (52.88)	1983 (59.19)	1459 (45.03)		
Race/Ethnicity, n (%)				χ^2 = 47.485	<0.001
Mexican American	965 (7.90)	361 (6.06)	604 (10.18)		
Other Hispanic	631 (5.26)	305 (5.30)	326 (5.20)		
Non-Hispanic White	3071 (69.38)	1661 (73.42)	1410 (64.36)		
Non-Hispanic Black	1199 (10.45)	507 (8.84)	692 (12.45)		
Other Race — Including Multi-Racial	604 (7.02)	327 (6.38)	277 (7.80)		
Education Level, n (%)				χ^2 = 170.997	<0.001
Less than 9th grade	577 (4.89)	155 (2.81)	422 (7.47)		
9—11th grade	805 (9.10)	276 (6.82)	529 (11.94)		
High School Grad/GED or Equivalent	1411 (20.83)	597 (16.80)	814 (25.83)		
Some College or AA degree	1887 (30.63)	990 (31.27)	897 (29.84)		
College Graduate or above	1790 (34.55)	1143 (42.30)	647 (24.93)		
PIR, Mean (S.E)	3.19 (0.06)	3.46 (0.06)	2.86 (0.07)	t = 8.99	<0.001
Smoking, n (%)				χ^2 = 114.171	<0.001
Never	3675 (57.93)	2066 (65.28)	1609 (48.80)		
Former smoker	1681 (26.08)	706 (23.66)	975 (29.09)		
Current smoker	1114 (15.99)	389 (11.06)	725 (22.11)		
Drinking, n (%)				χ^2 = 18.673	<0.001
<1 times/week	4074 (56.43)	1960 (53.97)	2114 (59.48)		
1—7 times/week	1674 (30.24)	911 (33.76)	763 (25.88)		
≥8 times/week	722 (13.33)	290 (12.27)	432 (14.64)		
Physical activity, n (%)				χ^2 = 8.367	0.004
No	3453 (47.68)	1590 (44.75)	1863 (51.32)		
Yes	3017 (52.32)	1571 (55.25)	1446 (48.68)		
BMI, n (%)				χ^2 = 0.942	0.815
Thin	69 (1.13)	26 (1.05)	43 (1.22)		
Normal	1557 (25.49)	783 (26.10)	774 (24.74)		
Overweight	2234 (35.16)	1082 (35.23)	1152 (35.07)		
Fat	2610 (38.22)	1270 (37.62)	1340 (38.96)		
Carbohydrate, gm/1000 kcal, Mean (S.E)	120.60 (0.60)	119.47 (0.67)	122.01 (0.79)	t = −3.03	0.004
Fiber, gm/1000 kcal, Mean (S.E)	9.03 (0.09)	9.14 (0.11)	8.88 (0.13)	t = 1.59	0.118
Energy, kcal, Mean (S.E)	2033.61 (15.50)	2036.40 (15.37)	2030.14 (25.75)	t = 0.23	0.821
Carbohydrate-to-fiber ratio, Mean (S.E)	15.85 (0.19)	15.38 (0.25)	16.43 (0.27)	t = −2.99	0.004
Diabetes, n (%)				χ^2 = 48.213	<0.001
No	5240 (86.34)	2722 (89.70)	2518 (82.17)		
Yes	1230 (13.66)	439 (10.30)	791 (17.83)		
Dyslipidemia, n (%)				χ^2 = 0.001	0.977
No	524 (7.42)	268 (7.41)	256 (7.44)		
Yes	5946 (92.58)	2893 (92.59)	3053 (92.56)		
Tooth lost, n (%)				χ^2 = 193.437	<0.001
No	1995 (38.32)	1384 (50.51)	611 (23.18)		
Yes	4475 (61.68)	1777 (49.49)	2698 (76.82)		
Antifungal drug and antibiotics, n (%)				χ^2 = 0.723	0.395
No	6294 (96.80)	3066 (96.55)	3228 (97.10)		
Yes	176 (3.20)	95 (3.45)	81 (2.90)		

S.E: standard error, GED: general equivalent diploma, PIR: ratio of family income to poverty, BMI: Body mass index.

Table 2 Association between carbohydrate-to-fiber ratio and the risk of periodontitis.

Variables	Model 1		Model 2		Model 3	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Carbohydrate-to-fiber ratio						
Q_4	Ref		Ref		Ref	
Q_1	0.69 (0.59–0.82)	<0.001	0.72 (0.60–0.85)	<0.001	0.82 (0.69–0.97)	0.017
Q_2	0.72 (0.61–0.85)	<0.001	0.66 (0.57–0.77)	<0.001	0.74 (0.63–0.87)	<0.001
Q_3	0.77 (0.65–0.90)	0.001	0.77 (0.65–0.91)	0.002	0.83 (0.71–0.97)	0.014

OR: odds ratio, CI: confidence interval, Ref: reference.
Q_1: 0–10.88, Q_2: 10.89–14.02, Q_3: 14.03–18.47, Q_4: ≥18.48.
Model 1: Unadjusted univariate logistic regression model.
Model 2: Multivariable logistic regression model adjusted for age, gender, race, education level and PIR.
Model 3: Multivariable logistic regression model adjusted for age, gender, race, education Level, PIR, smoking, drinking, physical activity, diabetes, tooth lost, and energy.

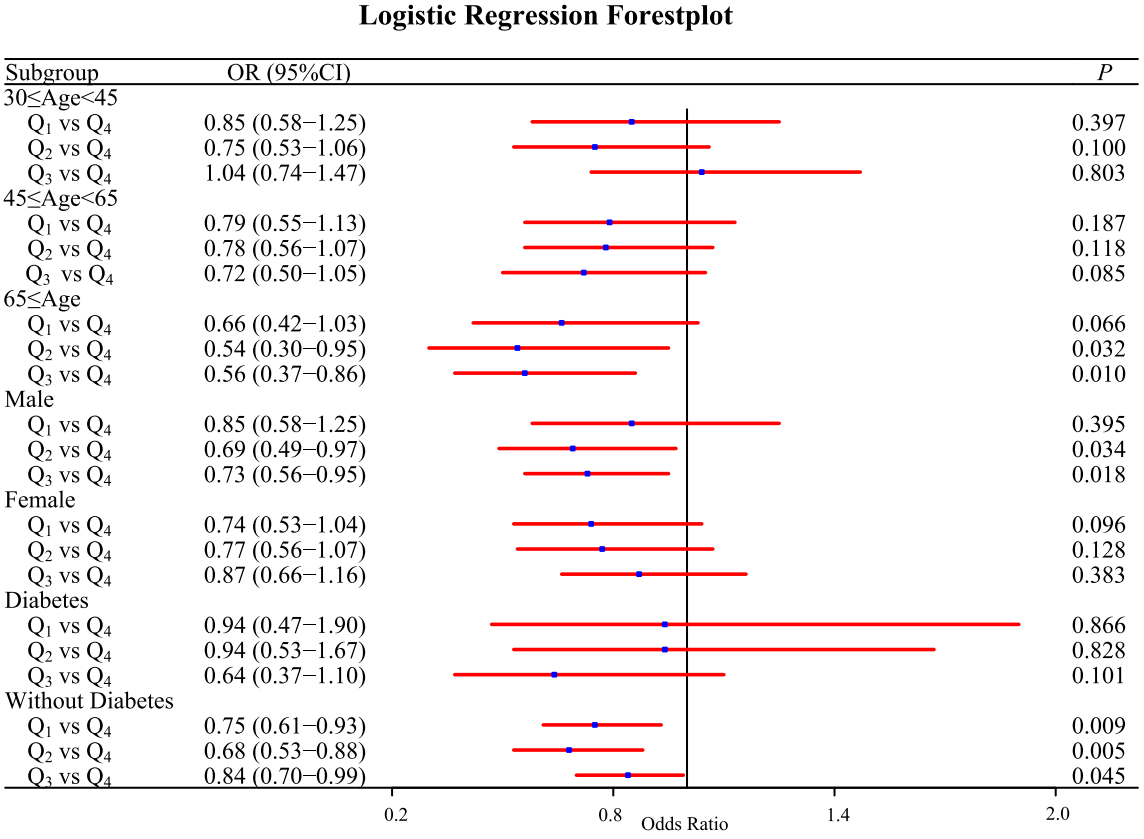

Figure 2 Forest plot showing the association between carbohydrate-to-fiber ratio and the risk of periodontitis in different subgroups.

which revealed that low carbohydrate-to-fiber ratio was associated with reduced risk of periodontitis. The potential mechanism might be that fibers might have an impact on anti-inflammatory response via Short Chain Fatty Acids (SCFAs), such as acetate, propionate, and butyrate, which are generated as byproducts of bacterial fermentation of prebiotics.[19] Decreased SCFAs, as found in a low fiber diet might increase the translocation of bacteria and pathogen-associated molecular patterns like lipopolysaccharide across the intestinal epithelial barrier, which induces systemic inflammation.[20,21] SCFAs also directly regulate cell-mediated immune responses through epigenetically regulating immune cells and the endothelium of the blood–brain barrier.[22] Conversely, they also enhance an

anti-inflammatory response vis increasing induction of regulatory T-cell and interleukin (IL)-10 release while decreasing tumor necrosis factor (TNF)-α and interferon (IFN)-γ release.[23,24]

Subgroup analysis revealed that low carbohydrate-to-fiber ratio was associated with reduced risk of periodontitis in people aged $\geq$65 years. We also identified that in males, low carbohydrate-to-fiber ratio was associated with reduced risk of periodontitis. Merchant et al. previously revealed that whole-grain and fiber intakes were inversely associated with and periodontitis risk in men.[25] Those without diabetes, decreased risk of periodontitis was observed in those with low carbohydrate-to-fiber ratio. Patients with diabetes might be in chronic inflammation status, and anti-inflammatory treatments might be provided in those patients.[26] As periodontitis is also a chronic inflammatory disease, anti-inflammatory interventions might decrease the risk of periodontitis, and the association between carbohydrate-to-fiber ratio and periodontitis might be not statistically different. There was no statistical association between carbohydrate-to-fiber ratio and periodontitis in diabetes patients. In this study, the carbohydrate and fiber intake of these patients were calculated based on the average value of the sum of the dietary and supplement intake on the first day and the sum of the dietary and supplement intake on the second day, and patients with diabetes had lower carbohydrate than those without (220.70 g vs 245.25 g) while the fiber intake was similar in those with and without diabetes (16.85 g vs 17.63 g). The data only represented the carbohydrate and fiber intake of these patients at that time point. However, patients with diabetes might receive respective treatments, and these might also affect the subsequent food-taking habits, and the association between carbohydrate-to-fiber ratio and periodontitis in diabetes patients might be affected. For males, those with old age, or people without diabetes, to decrease the carbohydrate-to-fiber ratio, especially increase the fiber intake might be encouraged.

The strengths of the current study were that carbohydrate-to-fiber ratio could better reflect the quality of dietary carbohydrate than one single index. All the samples were collected from NHANES, which was more representative. Additionally, the periodontal examination in NHANES covering 28 teeth with 6 positions per tooth, which was relatively comprehensive. There were several limitations. Firstly, this was a cross-sectional study, no causal relationship between carbohydrate-to-fiber and periodontitis could be inferred. Dietary reviews might result in recall bias, but this study excluded samples with implausible energy intake or extreme values and used the mean values of two days, which might help decrease the influence of recall bias. In the future, more well-designed studies were required to validate the findings in our study.

The association between carbohydrate-to-fiber ratio and the risk of periodontitis was assessed in this study, which depicted that low carbohydrate-to-fiber ratio was associated with decreased risk of periodontitis especially in those aged $\geq$65 years, males or people without diabetes. The findings suggested the importance of increasing dietary carbohydrate quality, especially fiber intake for the management of periodontitis.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

Acknowledgments

None.

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