Original Article

Relationship between dietary patterns and prediabetes, undiagnosed or diagnosed diabetes mellitus among adults in Qingdao: A cross-sectional study

Guoqiang Luo MS[1†], Xiaojing Li MS[2†], Xia Zhao MS[3], Lili He BS[2], Xiaojing Lv MS[2], Enqiang Feng MS[2], Nan Cui PhD[4], Jing Cui PhD[2], Yongye Sun PhD[1], Jianping Sun PhD[2]

[1]School of Public Health, Qingdao University, Qingdao, China
[2]Qingdao Centers for Disease Control and Prevention/Qingdao Institute for Preventive Medicine, Qingdao China
[3]Qingdao Stomatological Hospital Affiliated to Qingdao University, Qingdao, China
[4]Hospital Management Institute, The Affiliated Hospital of Qingdao University, Qingdao, China
[†]Both authors contributed equally to this manuscript

Background and Objectives: To identify the main dietary patterns of adults and investigate the cross-sectional associations of these dietary patterns with prediabetes and undiagnosed or diagnosed diabetes mellitus (DM) in Qingdao, China. **Methods and Study Design:** This study included 4,457 participants who were administered the semi-quantitative food frequency questionnaire (FFQ). Dietary patterns were identified through principal component analysis (PCA). Logistic regression analysis was performed to determine the associations of each pattern with the risks of prediabetes and undiagnosed or diagnosed DM. **Results:** PCA revealed two major dietary patterns. The Fruits–Vegetables and Poultry–Seafood patterns were not significantly associated with the risk of prediabetes in either crude or adjusted models (all p>0.05). The highest quartile of the Fruits–Vegetables pattern was significantly associated with decreased risks of undiagnosed DM (crude: OR=0.55, 95% CI: 0.41–0.72; Model 1: OR=0.61, 95% CI: 0.46–0.81; Model 2: OR=0.57, 95% CI: 0.42–0.77; Model 3: OR=0.56, 95% CI: 0.41–0.76) and diagnosed DM (crude: OR=0.51, 95% CI: 0.34–0.75; Model 1: OR=0.59, 95% CI: 0.39–0.88; Model 2: OR=0.60, 95% CI: 0.39–0.93; Model 3: OR=0.59, 95% CI: 0.38–0.91) compared with the lowest quartile in crude and adjusted models. The Poultry–Seafood pattern was not significantly associated with the risk of undiagnosed or diagnosed DM in crude or adjusted models (all p>0.05). **Conclusions:** The Fruits–Vegetables pattern was associated with a decreased risk of undiagnosed or diagnosed DM.

Key Words: dietary pattern, prediabetes, diabetes mellitus, Chinese

INTRODUCTION

Diabetes mellitus (DM) comprises a heterogeneous group of chronic metabolic disorders characterized by pathoglycemia attributable to a defect in insulin action, insulin secretion, or both.[1] Undiagnosed DM is a pathoglycemic condition that is yet to be recognised.[2] Approximately half of those with DM globally are estimated to be undiagnosed.[3] Prediabetes is marked by elevated blood glucose concentration that are still below the threshold for DM diagnosis.[4] In 2021, the International Diabetes Federation estimated that the global prevalence of prediabetes and DM was 16.8% (860 million)[3] and 10.5% (536.6 million) among adults aged 20–79 years, respectively.[5] In China, in 2018, the estimated standardized prevalence of prediabetes and DM was 38.1% (95% CI: 36.4%–39.7%) and 12.4% (95% CI: 11.8%–13.0%), respectively, in adults aged 18 years or more.[6] Prediabetes and DM have a major impact on physical and mental health, imposing a burden on the affected individuals, families, communities, and countries world-wide.[7-9] DM-related health expenditure and DM-related complications and mortality are increasing in China.[10] Thus, preventing DM prevention and reducing its complications have become public health priorities.

Genetic and behavioral factors, especially dietary patterns, play a crucial role in the pathogenesis of DM.[11-14] Dietary patterns are effective nonpharmacological strategies for glycemic control.[15,16] They reflect dietary choice and behavior, and the whole diet, rather than individual nutrients and bioactive components, is more strongly as-

Corresponding Author: Dr Jianping Sun, Qingdao Centers for Disease Control and Prevention/Qingdao Institute for Preventive Medicine, Qingdao, 266033, China.
Tel: +86-532-85623919
Email: qdcdcsjp@126.com
Dr Yongye Sun, School of Public Health, Qingdao University, Qingdao, China
Tel: +86-138-63980712
Email: sunnyleaf@qdu.edu.cn
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sociated with disease risk.[17] In addition, most current research examines the associations between dietary patterns and pathoglycemia in Western populations. A systematic review revealed that healthy dietary patterns, such as the Mediterranean-style diet, the "Dietary Approaches to Stop Hypertension" diet, and a healthy plant-based diet, have benefits for the prevention and management of pathoglycemia.[18] However, controversial results have been obtained regarding the association of dietary patterns with prediabetes or DM risk.[19-23] A prospective cohort study demonstrated that the prudent dietary pattern was negatively associated with hyperglycemia in middle-aged and older Korean women.[19] However, a cross-sectional study reported that the prudent dietary pattern was not significantly related to the risk of prediabetes in Taiwan, China.[21] Studies have demonstrated that Western dietary patterns and dietary patterns with high meat consumption increase the risks of prediabetes and DM.[20,21,24] However, a prospective cohort study reported that the dietary pattern with high meat consumption was not significantly associated with prediabetes and DM risks in Henan, China.[22] Few studies have explored the relationship of dietary patterns with the risks of prediabetes and undiagnosed and diagnosed DM. One cross-sectional study involving 1,305 Germans reported that adults on the Western dietary pattern had significantly higher risks of prediabetes and undiagnosed and diagnosed DM than adults on the prudent pattern.[25] To the best of our knowledge, no recent study has investigated the association of dietary patterns with pathoglycemia in the eastern coastal areas of China. Studies on the relationship between dietary patterns and prediabetes or type 2 diabetes mellitus risk in China have been conducted in inland cities, such as Henan[22] or Xinjiang.[26] Therefore, by using data from a large population-based cross-sectional survey, this study aimed to identify the main dietary patterns in adults and investigate the cross-sectional association between these identified dietary patterns and the risk of prediabetes and undiagnosed or diagnosed DM in Qingdao, China.

METHODS

Study population

This cross-sectional study was conducted using data from the Qingdao Diabetes Prevention Program, a community-based health-promoting program focusing on hyperglycemia and risk factors in adults. This cross-sectional study was conducted in three cities and three villages in Qingdao, China, with a sample of 6,000 adults aged 35–74 years recruited through four-stage stratified random sampling (Figure 1).[27,28] This study was conducted in 2009. A total of 5,110 participants completed the cross-sectional survey, and the response rate was 85.2%. Finally, this study included 4,457 participants after excluding individuals without information on fasting plasma glucose (FPG) (n=28), 2-hour postload plasma glucose (2h PG) in undiagnosed DM (n=441), and dietary intake (n=103) as well as patients with cardio-cerebrovascular diseases (n=67) and malignant tumors (n=14). The research protocols were formally approved by Qingdao Municipal Center for Disease Control and Prevention in January 2008. Moreover, all participants provided in-

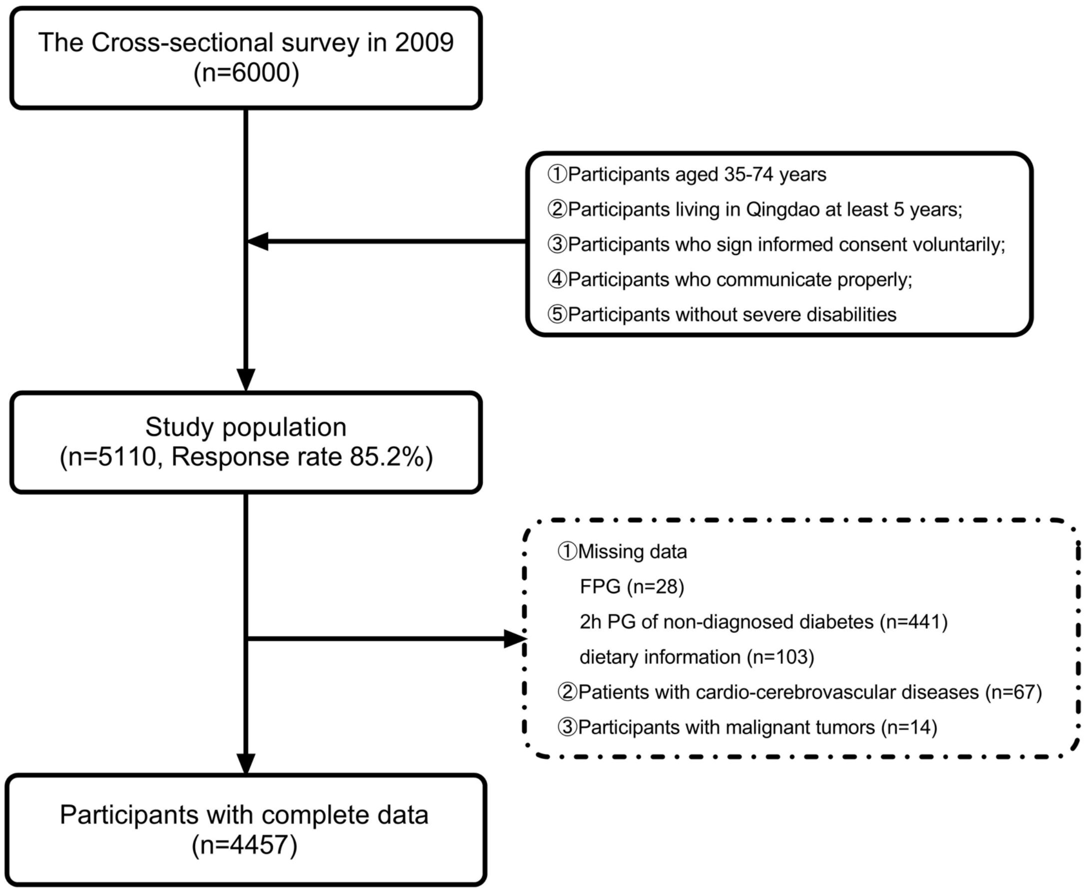

Figure 1. Flow chart for the study population selection of this cross-sectional study.

formed consent after they were provided a detailed explanation of the research procedures.

Data collection

For each participant, well-trained and qualified investigators used a standard questionnaire to collect information on general demographic characteristics (age, sex, educational level, marital status, urban–rural distribution, personal monthly income, and occupational physical activity), self-reported diagnoses of DM and other chronic diseases, self-reported family history of DM, and behavioral factors (smoking status) through face-to-face interviews. The education level was divided into primary school and below, junior high school, and senior high school and college. Marital status was assessed dichotomously: married (cohabiting and married) or unmarried (single, widowed, or divorced). Personal monthly income was classified into three categories: ≤599 RMB/M, 600–1,999 RMB/M, and ≥2,000 RMB/M. Smoking status was grouped into two categories: "yes" and "no". Occupational physical activity was categorized into low (salesperson, waiter, and teacher), moderate (student, driver, and electrician), and high (worker, miner, and dancer).

Anthropometric assessment

The well-trained health investigators measured weight, height, and blood pressure using standard anthropometric measurement methods. Patients' weight, in light clothes and without shoes, was measured to an accuracy of 0.1 kg by using a digital scale, and height was measured to an accuracy of 0.1 m by using a stadiometer. BMI was calculated as weight divided by the square of height. Blood pressure measurements were obtained noninvasively and intermittently by using standard mercury sphygmomanometers, the upper-arm cuff was placed on the nondominant arm for acquiring three consecutive measurements at a 5-minute interval. Hypertension was defined as systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, or taking antihypertensive medication.

Biochemical assessment

Venous blood samples were collected from all individuals after 8–12-hour fasting. In addition, venous blood samples were obtained for determining 2h PG after an oral 75 g glucose tolerance test in individuals without DM. FPG, 2h PG, triglyceride (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) were measured using the Olympus automatic biochemical analyzer at the Central Laboratory of Qingdao Endocrinology and Diabetes Hospital; however, 2h PG was not measured in individuals with DM diagnosis.

Assessment of dietary data

Dietary intake over the previous 12 months was evaluated using a validated semi-quantitative FFQ. This semi-quantitative FFQ achieved reasonable reliability and validity for all food items related to frequency and amount. In this cross-sectional study, the semi-quantitative FFQ was administered by well-trained health investigators. This semi-quantitative FFQ consisted of 45 food items related to the frequency (never, times per day, times per week, times per month, and times per year) and amount (gram per time) of food commonly consumed by participants. The food was classified as staple food, red meat, poultry, offal, seafood, eggs, soybean products, vegetables, milk or products, fruits, nuts, alcohol beverages, and beverages (Supplementary Table 1). The energy from daily intake was calculated based on the frequency and the amount of food, as determined through the semi-quantitative FFQ, by using Chinese Food Composition Tables.

Outcome definition

Prediabetes and DM were defined based on FPG and 2h PG according to the diagnostic criteria of the American Diabetes Association (2018).[29] Prediabetes was defined as 5.6 mmol/L ≤ FPG <7.0 mmol/L or 7.8 mmol/L ≤ 2h PG <11.1 mmol/L. Undiagnosed DM was confirmed based on FPG ≥7.0 mmol/L or 2h PG ≥11.1 mmol/L among participants without DM diagnosis. Diagnosed DM was determined as FPG ≥7.0 mmol/L or 2h PG ≥11.1 mmol/L previously measured by health-care professional, regardless of the current FPG concentration of participants. This cross-sectional study focused on prediabetes and undiagnosed and diagnosed DM.

Statistical analysis

Normal continuous data are presented as mean ± standard deviation (SD), and their differences were assessed using one-way ANOVA. Nonnormal continuous data are presented as median and quartile (median (p25, p75)) and their differences were assessed using the Kruskal–Wallis method. Sex, urban–rural distribution, education level, marital status, personal monthly income, family history of DM, occupational physical activity, smoking status, and hypertension were analyzed as categorical variables. Categorical data are presented as number and percentage, and the differences were compared using the χ^2 test.

Dietary patterns were identified through PCA according to 13 food groups (Table S1). In this analysis, dietary patterns were categorized according to the intake (g/day) of each food group. The correlated patterns with higher interpretability were obtained using orthogonal rotation (varimax) in PCA. After the eigenvalues, scree plot, and interpretability were evaluated, the components of dietary patterns with the eigenvalue of >1.2 were retained in the analysis. Individual food groups with a |factor loading| ≥0.25 were considered to importantly contribute to the dietary patterns. Moreover, the factor scores for dietary pattern were calculated as the sum of the products of the factor loading coefficients and standardized daily intake of each food group. Dietary patterns were grouped into quartiles according to the factor scores. For the quartile of dietary pattern, the lowest quartile was regarded as the reference. Spearman's rank correlation coefficient was used to explore the correlation between dietary patterns and food groups, anthropometric measurements, and biochemical characteristics. Logistic regression analysis was performed to examine the association of each dietary pattern with the risks of prediabetes and undiagnosed and diagnosed DM by using three models. Model 1 was adjusted for age and sex. Model 2 was further adjusted for education level, marital status, urban–rural distribution, personal monthly income, family history of DM, occupational physical activity, smoking status, hypertension, BMI, and TG based on Model 1. Model 3 was further adjusted for energy intake based on Model 2. ORs with 95% CIs were calculated in this logistic regression analysis. All statistical analyses were conducted using SPSS24.0 (IBM Corp.). Two-sided $p<0.05$ was considered significant.

RESULTS

Participant characteristics

A total of 4,457 participants (1,760 men and 2,697 women) were included in this final analysis, and the mean age (SD) was 52.3 (10.8) years. Tables 1 and 2 provide the characteristics of participants according to FPG and 2h PG concentration. The overall prevalence of prediabetes, undiagnosed DM, and diagnosed DM was 29.8%, 12.4%, and 5.0%, respectively. Significant differences were observed in age, sex, educational level, marital status, urban–rural distribution, personal monthly income, family history of DM, occupational physical activity, smoking status, and hypertension among the different groups (all $p<0.05$) (Table 1). In addition, significant differences were found in BMI, FPG, 2h PG, TG, TC, HDL-C, and LDL-C among the different groups (all $p<0.05$) (Table 2).

Definition of dietary patterns

Figure 2 presents the scree plot for the identification of dietary patterns obtained through PCA and the distribution of the factor loadings of all components. Table 3 lists the two-cluster dietary patterns and the factor interpretability for the corresponding food items. The two-cluster dietary patterns were obtained using the scree plot, eigenvalue (Figure 2), and factor interpretability (Table 3), with a cumulative contribution rate of 39.69% to the total variation in dietary patterns. The first pattern, named Fruits–Vegetables dietary pattern, was characterized by the high consumption of fruits, vegetables, and nuts. The second dietary pattern, named Poultry–Seafood dietary pattern, was characterized by the high consumption of poultry, seafood, and red meat.

The distribution of patient characteristics by the quartile of the dietary pattern is presented in Tables 4 and 5. For each pattern, the participants were grouped into quartiles based on the dietary pattern scores obtained using the semi-quantitative FFQ and factor loadings. For the Fruits–Vegetables dietary pattern, compared with those in the lowest quartile, participants in the highest quartile had a significantly lower age, BMI, 2h PG, TG, and TC; a lower percentage of these participants had an education level of senior high school or higher, high personal monthly income, hypertension, high total energy intake, and high occupational physical activity; and a high percentage of these participants resided in rural areas (all $p<0.05$). For the Poultry–Seafood dietary pattern, compared with those in the lowest quartile, participants in the highest quartile had a significantly lower age and 2h PG; a lower percentage of these participants were women, had an education level of senior high school or higher, had low occupational physical activity, were smokers, and had high BMI and total energy intake; and a higher percentage of these participants were married and residing in rural areas (all $p<0.05$) (Tables 4 and 5).

Table 6 presents the correlation of dietary patterns with food groups, anthropometric measurements, and biochemical characteristics. In the Fruits–Vegetables dietary pattern, the highest correlation coefficients were found for vegetables ($r=0.699$, $p<0.001$) and fruits ($r=0.552$, $p<0.001$). In the Poultry–Seafood dietary pattern, the highest correlation coefficients were found for poultry ($r=0.655$, $p<0.001$) and seafood ($r=0.633$, $p<0.001$). Moreover, the Fruits–Vegetables dietary pattern was negatively correlated with FPG ($r=-0.044$, $p=0.003$), 2h PG ($r=-0.071$, $p<0.001$), TG ($r=-0.046$, $p=0.002$), and TC ($r=-0.054$, $p<0.001$). The Poultry–Seafood dietary pattern was positively correlated with BMI ($r=0.036$, $p=0.016$) and FPG ($r=0.034$, $p=0.022$) and negatively correlated with 2h PG ($r=-0.046$, $p=0.003$). In the two dietary patterns, the intake of the characteristic food increased as the factor score increased. Taking the Fruits–Vegetables die-

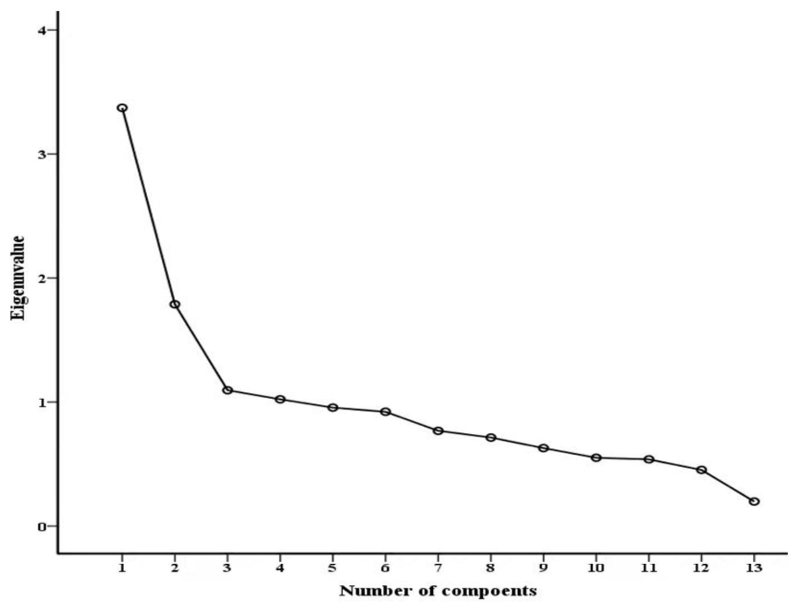

Figure 2. Scree plot for extraction of dietary patterns by PCA.

Table 1. Distribution of socioeconomic characteristics in participants according to the grouping[†]

Variables	Control (n=2351)	Prediabetes (n=1330)	Undiagnosed DM (n=551)	Diagnosed DM (N=225)	*p*-value
Age, year (Mean±SD)	49.4±10.1	54.0±10.5	58.2±10.3	59.0±9.6	<0.001
Sex, n (%)					<0.001
Men	887 (37.7)	552 (41.5)	249 (45.2)	72 (32.0)	
Women	1464 (62.3)	778 (58.5)	302 (54.8)	153 (68.0)	
Educational attainment, n (%)					<0.001
Primary school and below	873 (37.1)	690 (51.9)	294 (53.4)	100 (44.4)	
Junior high school	1008 (42.9)	449 (33.8)	178 (32.3)	64 (28.4)	
Senior high school or higher	470 (20.0)	191 (14.4)	79 (14.3)	61 (27.1)	
Marital status, n (%)					<0.001
Married	2232 (94.9)	1245 (93.6)	491 (89.1)	203 (90.2)	
Unmarried	119 (5.1)	85 (6.4)	60 (10.9)	22 (9.8)	
Urban-rural distribution, n (%)					<0.001
Urban living	567 (24.1)	224 (16.8)	130 (23.6)	112 (49.8)	
Rural living	1784 (75.9)	1106 (83.2)	421 (76.4)	113 (50.2)	
Personal monthly income (RMB/M), n (%)					0.002
≤599	1283 (54.6)	792 (59.5)	328 (59.5)	117 (52.0)	
600-1999	929 (39.5)	455 (34.2)	193 (35.0)	84 (37.3)	
≥2000	139 (5.9)	83 (6.2)	30 (5.4)	24 (10.7)	
Family history of DM, n (%)					0.001
No	2163 (92.0)	1207 (90.8)	472 (85.7)	157 (69.8)	
Yes	188 (8.0)	123 (9.2)	79 (14.3)	68 (30.2)	
Occupational physical activity, n (%)					<0.001
Low	210 (8.9)	107 (8.0)	65 (11.8)	48 (21.3)	
Moderate	166 (7.1)	69 (5.2)	25 (4.5)	21 (9.3)	
High	1975 (84.0)	1154 (86.8)	461 (83.7)	156 (69.3)	
Smoking, n (%)					0.001
No	1759 (74.8)	989 (74.4)	386 (70.1)	188 (83.6)	
Yes	592 (25.2)	341 (25.6)	165 (29.9)	37 (16.4)	
Hypertension, n (%)					<0.001
No	1515 (64.7)	596 (44.9)	188 (34.3)	64 (28.7)	
Yes	827 (35.3)	731 (55.1)	360 (65.7)	159 (71.3)	

[†]Continuous data are presented as mean and standard deviation, and using one-way ANOVA assessed the *p* value.
Categorical data are presented as numbers and percentages, and using χ^2 test assessed the *p* value.

Table 2. Distribution of anthropometric and biochemical characteristics in the participants of each group

Variables	Control (n=2351)	Prediabetes (n=1330)	Undiagnosed DM (n=551)	Diagnosed DM (n=225)	*p*-value
BM I(kg/m^2)	24.2 (22.1,26.6)	25.2 (22.8,27.7)	25.9 (23.2,28.4)	25.7 (23.5,27.9)	<0.001
FPG (mmol/L)	5.40 (5.10,5.60)	6.10 (5.60,6.30)	7.10 (6.20,8.10)	9.00 (7.55,12.1)	<0.001
2h PG (mmol/L)	5.80 (5.10,6.60)	8.20 (6.90,9.10)	12.0 (11.1,14.2)	9.20 (6.80,14.3)	<0.001
TG (mmol/L)	1.00 (0.74,1.49)	1.26 (0.89,1.87)	1.46 (1.02,2.19)	1.71 (1.21,2.56)	<0.001
TC (mmol/L)	5.01 (4.43,5.66)	5.32 (4.72,6.01)	5.67 (4.93,6.42)	5.52 (4.93,6.17)	<0.001
HDL-C (mmol/L)	1.61 (1.39,1.89)	1.59 (1.37,1.89)	1.55 (1.37,1.82)	1.43 (1.27,1.64)	<0.001
LDL-C (mmol/L)	2.80 (2.30, 3.33)	2.97 (2.48,3.57)	3.25 (2.59,3.83)	3.07 (2.34,3.69)	<0.001
Total energy intake (kcal/d)	1599 (1089,2189)	1573 (1077,2228)	1575 (1093,2250)	1528 (1063,2167)	0.877

BMI: body mass index; FPG: fasting plasm glucose; 2h PG: 2-hour post load plasma glucose; TG: triglyceride; TC: total cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol.

†Continuous data are presented as median and quartile (median (p25, p75)), and using Kruskal–Wallis method assessed the *p* value.

Table 3. Dietary patterns based on factor loading from semi-quantitative FFQ

Food groups	Fruits-Vegetables pattern	Poultry-Seafood pattern
Fruits	0.880	-
Vegetables	0.865	-
Nuts	0.659	-
Staple food	0.618	0.438
Poultry	-	0.671
Seafood	0.314	0.636
Red meat	-	0.627
Offal	-	0.594
Soybean products	0.447	0.476
Eggs	0.308	0.425
Alcohol beverages	-	0.295
Beverages	-	0.293
Milk or milk products	-	-
Variance of intake explained (%)	21.190	18.499

FFQ: food frequency questionnaire.

Table 4. Distribution of socioeconomic characteristics by the quartiles of dietary pattern†

Variables	Fruits-Vegetables pattern			Poultry-Seafood pattern		
	Q1 (n=1114)	Q4 (n=1114)	*p*-value	Q1 (n=1114)	Q4 (n=1114)	*p*-value
Age, year (Mean±SD)	53.1±10.9	50.9±10.5	<0.001	53.0±11.3	50.8±10.5	<0.001
Sex, n (%)			0.514			<0.001
Men	424 (38.1)	440 (39.5)		359 (32.2)	545 (48.9)	
Women	690 (61.9)	674 (60.5)		755 (67.8)	569 (51.1)	
Educational attainment, n (%)			0.005			<0.001
Primary school and below	432 (38.8)	439 (39.4)		590 (53.0)	344 (30.9)	
Junior high school	432 (38.8)	483 (43.4)		375 (33.7)	497 (44.6)	
Senior high school or higher	250 (22.4)	192 (17.2)		149 (13.4)	273 (24.5)	
Marital status, n (%)			0.053			0.011
Married	1034 (92.8)	1056 (94.8)		1031 (92.5)	1060 (95.2)	
Unmarried	80 (7.2)	58 (5.2)		83 (7.5)	54 (4.8)	
Urban-rural distribution, n (%)			<0.001			<0.001
Urban living	379 (34.0)	231 (20.7)		166 (14.9)	347 (31.1)	
Rural living	735 (66.0)	883 (79.3)		948 (85.1)	767 (68.9)	
Personal monthly income (RMB/M), n (%)			<0.001			<0.001
≤599	520 (46.7)	620 (55.7)		684 (61.4)	497 (44.6)	
600-1999	493 (44.3)	429 (38.5)		374 (33.6)	508 (45.6)	
≥2000	101 (9.1)	65 (5.8)		56 (5.0)	109 (9.8)	
Family history of DM, n (%)			0.535			0.110
No	1001 (89.9)	992 (89.0)		1010 (90.4)	987 (88.6)	
Yes	113 (10.1)	122 (11.0)		104 (9.3)	127 (11.4)	
Occupational physical activity, n (%)			<0.001			<0.001
Low	179 (16.1)	89 (8.0)		96 (8.6)	120 (10.8)	
Moderate	87 (7.8)	74 (6.6)		53 (4.8)	94 (8.4)	
High	848 (76.1)	951 (85.4)		965 (86.6)	900 (80.8)	
Smoking, n (%)			0.153			<0.001
No	856 (76.8)	827 (74.2)		889 (79.8)	765 (68.7)	
Yes	258 (23.2)	287 (25.8)		225 (20.2)	349 (31.3)	
Hypertension			0.020			0.499
No	552 (50.0)	612 (55.0)		570 (51.5)	588 (52.9)	
Yes	551 (50.0)	501 (45.0)		537 (48.5)	523 (47.1)	

†Continuous data are presented as mean and standard deviation, and using one-way ANOVA assessed the *p* value.
Categorical data are presented as numbers and percentages, and using $\chi 2$ test assessed the *p* value.

tary pattern as an example, the intake of vegetables and fruits increased as the score increased.

Association between dietary patterns and prediabetes

Table 7 presents the association between dietary patterns and prediabetes risk through logistic regression analysis. In the crude and adjusted models, the highest quartiles of the Fruits–Vegetables dietary pattern and the Poultry–Seafood dietary pattern were not significantly associated with the risk of prediabetes compared with the lowest quartile (all p>0.05).

Association between dietary patterns and undiagnosed DM

Table 7 presents the association between dietary patterns and undiagnosed DM risk. In the crude model, the highest quartile of the Fruits–Vegetables dietary pattern was significantly associated with a decreased risk of undiagnosed DM (OR=0.55, 95% Cl: 0.41–0.72) compared with the lowest quartile. Nevertheless, the highest quartile of the Poultry–Seafood dietary pattern was not significantly associated with undiagnosed DM risk in crude models. In all adjusted models (Models 1–3), the highest quartile of the Fruits–Vegetables dietary pattern was significantly associated with undiagnosed DM risk (Model 1: OR=0.61, 95% CI: 0.46–0.81; Model 2: OR=0.57, 95% CI: 0.42–0.77; Model 3: OR=0.56, 95% CI: 0.41–0.76) compared with the lowest quartile. However, the Poultry–Seafood dietary pattern was still not significantly associated with undiagnosed DM risk in all Models 1–3.

Association between dietary patterns and diagnosed DM

Table 7 presents the association between dietary patterns and diagnosed DM risk. In the crude model, the Fruits–Vegetables dietary pattern was significantly associated with a decreased risk of diagnosed DM (OR=0.51, 95% Cl: 0.34–0.75) compared with the lowest quartile. However, the Poultry–Seafood dietary pattern was not significantly associated with diagnosed DM risk in the crude model. In all adjusted models (Models 1–3), the Fruits–Vegetables dietary pattern was significantly associated with diagnosed DM risk (Model 1: OR=0.59, 95% CI: 0.39–0.88; Model 2: OR=0.60, 95% CI: 0.39–0.93; Model 3: OR=0.59, 95% CI: 0.38–0.91) compared with the lowest quartile. The Poultry–Seafood dietary pattern was not significantly associated with diagnosed DM risk in all Models 1–3.

DISCUSSION

Pathoglycemia is a cluster of risk factors that increases the risk of cardiovascular- and cerebrovascular disease–related mortality by 3–4 times.[30] Dietary patterns have

Table 5. Distribution of anthropometric and Biochemical characteristics by the quartiles of dietary pattern†

Variables	Fruits-Vegetables pattern			Poultry-Seafood pattern		
	Q1 (n=1114)	Q4 (n=1114)	*p*-value	Q1 (n=1114)	Q4 (n=1114)	*p*-value
BMI (kg/m^2)	24.9 (22.5, 27.4)	24.9 (22.7, 27.3)	0.023	24.5 (22.3, 27.3)	25.0 (22.7, 27.4)	0.098
FPG (mmol/L)	5.60 (5.30, 6.30)	5.60 (5.20, 6.10)	0.008	5.60 (5.20, 6.10)	5.70 (5.30, 6.20)	0.030
2h PG (mmol/L)	6.70 (5.60, 8.43)	6.30 (5.30, 8.00)	<0.001	6.80 (5.60, 8.50)	6.50 (5.30, 8.00)	0.006
TG (mmol/L)	1.21 (0.86, 1.83)	1.12 (0.78, 1.71)	0.007	1.12 (0.81, 1.73)	1.16 (0.80, 1.75)	0.552
TC (mmol/L)	5.29 (4.65, 5.96)	5.10 (4.53, 5.79)	0.002	5.15 (4.54, 5.86)	5.23 (4.61, 5.91)	0.130
HDL-C (mmol/L)	1.60 (1.37, 1.88)	1.57 (1.36, 1.85)	0.157	1.58 (1.37, 1.88)	1.59 (1.35, 1.87)	0.756
LDL-C (mmol/L)	2.95 (2.40, 3.54)	2.86 (2.36, 3.48)	0.303	2.88 (2.374, 3.47)	2.91 (2.40, 3.51)	0.399
Total energy intake (kcal/d)	1121(414, 11782)	2013 (1446, 2819)	<0.001	1314 (611, 1932)	1989 (1394, 2860)	<0.001

BMI: body mass index; FPG: fasting plasm glucose; 2h PG: 2-hour post load plasma glucose; TG: triglyceride; TC: total cholesterol: HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol.
†Continuous data are presented as median and quartile (median (p25, p75)), and using Kruskal–Wallis method assessed the *p* value.

Table 6. The relationship between dietary patterns and food groups, anthropometric and biochemical characteristics (r_s, p)†

	Fruits-Vegetables pattern	Poultry-Seafood pattern
Staple food	0.575 (<0.001)	0.442 (<0.001)
Red meat	0.278 (<0.001)	0.589 (<0.001)
Poultry	0.039 (0.009)	0.655 (<0.001)
Offal	-0.082 (<0.001)	0.475 (<0.001)
Seafood	0.338 (<0.001)	0.633 (<0.001)
Egg	0.378 (<0.001)	0.397 (<0.001)
Soybean products	0.297 (<0.001)	0.537 (<0.001)
Vegetables	0.699 (<0.001)	0.187 (<0.001)
Milk or Milk products	0.122 (<0.001)	0.192 (<0.001)
Fruits	0.552 (<0.001)	0.160 (<0.001)
Nuts	0.380 (<0.001)	0.092 (<0.001)
Alcohol beverages	0.118 (<0.001)	0.261 (<0.001)
Beverages	0.074 (<0.001)	0.130 (<0.001)
BMI	-0.014 (0.343)	0.036 (0.016)
FPG	-0.044 (0.003)	0.034 (0.022)
2h PG	-0.071 (<0.001)	-0.046 (0.003)
TG	-0.046 (0.002)	0.002 (0.894)
TC	-0.054 (<0.001)	0.022 (0.136)
HDL-C	-0.026 (0.081)	-0.009 (0.532
LDL-C	-0.028 (0.063)	0.018 (0.231)

BMI: body mass index; FPG: fasting plasm glucose; 2h PG: 2-hour post load plasma glucose; TG: triglyceride; TC: total cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol.
†The correlation coefficient was calculated by Spearman's rank correlation.

Table 7. Risk for prediabetes, undiagnosed and diagnosed DM according factor scores to by dietary pattern

	n	Crude†	Model 1‡	Model 2§	Model 3¶
Prediabetes					
Fruits-Vegetables pattern					
Q1	318	1.00	1.00	1.00	1.00
Q4	338	0.94 (0.78,1.14)	0.99 (0.82,1.22)	0.94 (0.76,1.15)	0.90 (0.73,1.11)
Poultry-Seafood pattern					
Q1	341	1.00	1.00	1.00	1.00
Q4	348	1.02 (0.84,1.23)	1.10 (0.90,1.33)	1.20 (0.98,1.48)	1.18 (0.96,1.45)
Undiagnosed DM					
Fruits-Vegetables pattern					
Q1	159	1.00	1.00	1.00	1.00
Q4	98	0.55 (0.41,0.72)	0.61 (0.46,0.81)	0.57 (0.42,0.77)	0.56 (0.41,0.76)
Poultry-Seafood pattern					
Q1	131	1.00	1.00	1.00	1.00
Q4	140	0.97 (0.74,1.26)	1.12 (0.85,1.48)	1.13 (0.84,1.51)	1.15 (0.85,1.56)
Diagnosed DM					
Fruits-Vegetables pattern					
Q1	75	1.00	1.00	1.00	1.00
Q4	43	0.51 (0.34,0.75)	0.59 (0.39,0.88)	0.60 (0.39,0.93)	0.59 (0.38,0.91)
Poultry-Seafood pattern					
Q1	75	1.00	1.00	1.00	1.00
Q4	43	0.90 (0.60,1.36)	1.17 (0.77,1.79)	0.95 (0.60,1.49)	0.94 (0.59,1.50)

†Crude: unadjusted.
‡Model 1 was adjusted for age and sex.
§Model 2 was adjusted for age, sex, educational attainment, marital status, urban-rural distribution, personal monthly income, family history of DM, occupational physical activity, smoking, hypertension, BMI, TG.
¶Model 3 was adjusted for age, sex, educational attainment, marital status, urban-rural distribution, personal monthly income, family history of DM, occupational physical activity, smoking, hypertension, BMI, TG and total energy intake.

been revealed to be significantly associated with prediabetes or DM. However, the current study is among the few studies that have explored the dietary patterns and their relationship with the risks of prediabetes, undiagnosed DM, and diagnosed DM in Qingdao along the east coast of China. We found that the two most representative dietary patterns were the Fruits–Vegetables dietary pattern and the Poultry–Seafood dietary pattern among adults in Qingdao. They explained 39.69% of the variation. Logistic regression analysis revealed that the Fruits–Vegetables dietary pattern was negatively associated with the risks of undiagnosed DM and diagnosed DM, but not with prediabetes risk. Moreover, the Poultry–Seafood dietary pattern was not associated with the risks of prediabetes and undiagnosed and diagnosed DM.

Of the two dietary patterns, the Fruits–Vegetables dietary pattern was the most prevalent and explained 21.19% of the variation. The Fruits–Vegetables dietary pattern is characterized by the intake of vegetables, fruits, nuts, staple food, and soybean products. The Fruits–Vegetables dietary pattern in the current study was similar to the Plant-Based dietary pattern and the prudent dietary pattern in previous research, which provided better control of glycemic markers in individuals with pathoglycemia.[25,31] In the present study, this dietary pattern had a negative association with undiagnosed and diagnosed DM risks, but not with prediabetes risk. A cross-sectional study involving 199 subjects aged between 20 and 65 years indicated that a prudent dietary pattern was not significantly related to the risk of prediabetes in Taiwan, China.[21] Similar results were found in a case–control study in Shahreza, Iran,[32] and a cohort study in Finland.[33] These results are similar to our present study findings. However, a Rotterdam cohort study involving 6,798 participants indicated that a more plant-based dietary pattern was associated with a reduced risk of prediabetes,[34] and similar results were found in a cross-sectional study in Henan province[22] and Jiangsu province,[24] China. The association of the Fruits–Vegetables dietary pattern with DM is controversial. The health and aging networks in Europe and the United States and a systematic review and meta-analysis showed no significantly decreased risk of DM from increasing the consumption of both vegetables and fruits.[35] Similarly, no significantly decreased risk was noted for fruit and vegetable intake in a meta-analysis by Hamer M.[36] These results are inconsistent with those of our present study. Nevertheless, three prospective cohort studies involving 200,727 men and women noted that the healthy plant-based dietary pattern was negatively associated with DM in pooled multivariable-adjusted analysis.[37] Similar results were obtained in cohort studies in Athens[38] and Rotterdam[34] as well as a systematic review of prospective observational studies.[39] Those results are consistent with our present study findings. In the past decade, accumulating evidence from clinical trials and observational studies has indicated that the plant-based dietary pattern reduces the risk of DM and improves hyperglycemic control in patients with DM.[40] The plant-based dietary pattern features different micro- and macro-nutrients, which might play a crucial role in mediating beneficial health effects.[41] In addition, the plant-based dietary pattern is the main source of fiber, antioxidants, phytochemicals, poly-unsaturated fatty acids, and plant protein.[41,42] In the plant-based dietary pattern, micro- and macro-molecules as well as their metabolic substrates influence various physiological functions through complex interdependence. The plant-based dietary pattern may provide better control of glycemia and may decrease inflammatory activity through multiple pathways of dietary intake and intestinal activity. The plant-based diet cannot explain all the observed effects on glycemic control.

The Poultry–Seafood dietary pattern, characterized by the high consumption of poultry, seafood, red meat, offal, and staple food, is common in the eastern coast of China. In the current study, the Poultry–Seafood dietary pattern is similar to the dietary pattern with high meat consumption and the Western dietary pattern in previous research.[25,43] This dietary pattern was not significantly associated with the risks of prediabetes, undiagnosed DM, and diagnosed DM in Qingdao, China. Previous observational studies have reported that the Western dietary or the dietary pattern with high meat consumption was detrimentally associated with prediabetes and DM risks,[21,24,33] which is not in accordance with our current study results. Sun Q et al. indicated that the dietary pattern with high meat consumption was not significantly associated with DM risk in people in Shanxi province, after adjustment for demographic characteristics, smoking status, and drinking habit.[44] A community-based case–control study involving 836 Uygur adults demonstrated that the "refined grains and meat" dietary pattern was significantly positively associated with T2DM in Urumqi, Xinjiang Uygur Autonomous Region, China.[26] A recent review of the association of the dietary pattern with the risk of T2DM noted that a diet high in red and processed meat seemed to increase the risk of T2DM.[31] These results are not consistent with our current study results. Based on the key roles of nutritional diversity and harmful ingredients in poultry and seafood, some mechanisms underlying the relationship between the Poultry–Seafood dietary pattern and DM risk have been explored. First, grouping poultry and seafood as the "meat dietary pattern" is similar to the protein type of red meat but with low fat content, which can reduce the risk of DM.[45-47] However, the long-chain omega-3 fatty acids of poultry and seafood, specifically docosahexaenoic acid and eicosapentaenoic acid, have been demonstrated to be beneficial for human health.[48] Moreover, persistent organic pollutants and heavy metals (e.g., mercury) in poultry and seafood can adversely affect human health.[48-50] Currently, the potential mechanisms underlying the relationship of poultry and seafood with hazardous material and body functions are unclear. In addition, the differences in preparation methods and types of poultry and seafood may affect the relationship between dietary patterns and DM risk in different countries.[51] The nutrient content and the degree of processing for the Poultry–Seafood dietary pattern or the dietary pattern with high meat consumption should be considered when interpreting the results of the present study. Future studies with detailed information on the type of meat or processed meat are warranted.

Strengths and limitations

Our study has several strengths. The large sample size increased the statistical power of our results. In addition, this study identified the major dietary patterns based on the quality control and assurance strategies of FFQ. However, the present study has some limitations. In this cross-sectional study, causality could not be determined, and further prospective longitudinal studies are needed to investigate the causal association between the dietary pattern and prediabetes or DM risk. In addition, the study participants were aged between 35 and 74 years in the eastern coastal city of China, thus, the current results should be cautiously extrapolated to the general population. Furthermore, dietary and socioeconomic information was self-reported by participants through recall, which might cause recall bias.

Conclusion

The Fruits–Vegetables dietary pattern was associated with decreased risks of undiagnosed and diagnosed DM in adults. Healthy dietary patterns high in fruits and vegetables are beneficial for preventing and improving DM management.

AUTHOR DISCLOSURES

The authors declare that they have no conflicts of interest.

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Supplementary table 1. List of the 13 food groups derived from the 45 items in semi-quantitative FFQ

Food groups	Examples of food items
Fruits	All kind of fresh fruit
Vegetables	Fresh vegetables, Dried vegetables, Pickled vegetables, Sauerkraut
Nuts	All kind of nuts
Staple food	Rice, Wheat, Flour, Millet, Sorghum, Corn, Sweet Potato, Yam, Taro, Potato, Fritters, Seedcake, Cake
Poultry	All kind of Poultry
Seafood	Sea Fish, Sea Shellfish, Sea Mollusks, Freshwater Fish, Freshwater Shellfish
Offal	All kind of offal
Red Meat	Beef, Lamb, Pork
Soybean Products	Tofu, Soy Milk, Dried Tofu, Shredded Tofu, All kind of dried beans
Alcohol Beverages	White spirit, Beer, Wine, Fruit Wine
Beverages	Fruit Juice, Other Juice
Milk or Milk Products	Fresh Milk, Yogurt, Cheese, Milk Powder
Eggs	All kind of Eggs

FFQ: food frequency questionnaire.

Supplementary table 2. Consumption of food groups according to quartile of two dietary patterns[†]

Food groups (g/day)	Fruits-Vegetables pattern Q1	Q2	Q3	Q4	*p* trend	Poultry-Seafood pattern Q1	Q2	Q3	Q4	*p* trend
Staple food	164	300	375	555	<0.001	207	306	356	525	<0.001
Red meat	48.0	66.3	77.0	103	<0.001	17.0	44.5	77.8	155	<0.001
Poultry	13.9	8.20	9.22	10.9	0.583	1.05	3.88	8.50	28.8	<0.001
Offal	11.2	5.09	4.40	6.61	0.265	0.42	1.57	4.72	20.6	<0.001
Seafood	47.7	62.5	77.5	139	<0.001	21.1	45.6	77.3	183	<0.001
Egg	20.3	39.7	48.8	66.4	<0.001	18.6	39.2	46.5	70.8	<0.001
Soybean products	29.1	38.5	53.1	118	<0.001	15.1	35.1	57.5	132	<0.001
Vegetables	60.3	207	305	509	<0.001	252	250	259	320	<0.001
Milk or Milk products	44.4	30.0	34.6	71.8	0.004	14.0	29.4	39.7	97.8	<0.001
Fruits	17.4	51.7	77.5	168	<0.001	77.3	62.8	79.9	94.3	0.098
Nuts	1.17	2.97	6.09	30.5	<0.001	9.96	7.22	8.56	15.0	0.238
Alcohol beverages	58.8	56.5	51.1	75.8	0.206	4.40	22.2	54.6	161	<0.001
Beverages	4.93	5.32	3.40	10.3	0.227	0.31	0.88	2.27	20.5	<0.001

[†]Unit is g/day. Q1-Q4, the quartiles for the factor scores.
p trend was assessed using the trend Chi-square tests.

Supplementary table 3. Risk for prediabetes, undiagnosed and diagnosed DM according intakes of food groups

Food groups	Crude[†]	Model 1[‡]	Model 2[§]
Prediabetes			
Staple food	1.000 (1.000,1.000)	1.000 (1.000,1.000)	1.000 (1.000,1.000)
Red meat	0.999 (0.998,1.000)	1.000 (0.999,1.000)	1.000 (0.999,1.001)
Poultry	1.002 (0.999,1.005)	1.002 (0.999,1.005)	1.002 (0.999,1.005)
Offal	0.998 (0.994,1.002)	0.999 (0.995,1.003)	0.999 (0.995,1.003)
Seafood	1.000 (1.000,1.001)	1.000 (1.000,1.001)	1.000 (1.000,1.001)
Egg	1.000 (0.999,1.001)	1.000 (0.998,1.001)	1.000 (0.999,1.001)
Soybean products	1.000 (0.999,1.000)	1.000 (0.999.1.001	1.000 (0.999,1.001)
Vegetables	1.000 (1.000,1.000)	1.000 (1.000,1.000)	1.000 (1.000,1.000)
Milk or Milk products	1.000 (1.000,1.000)	1.000 (1.000,1.000)	1.000 (1.000,1.000)
Fruits	1.000 (0.999,1.000)	1.000 (0.999,1.000)	1.000 (0.999,1.000)
Nuts	1.000 (0.998,1.002)	1.000 (0.998,1.002	1.000 (0.998,1.003)
Alcohol beverages	1.000 (1.000,1.001)	1.000 (1.000,1.001)	1.000 (1.000,1.001)
Beverages	1.000 (0.998,1.001)	1.000 (0.999,1.002)	1.001 (0.999,1.002)
Undiagnosed DM			
Staple food	1.000 (0.999,1.000)	1.000 (0.999,1.000)	1.000 (0.999,1.000)
Red meat	1.000 (0.999,1.002)	1.001 (1.000,1.002)	1.001 (1.000,1.002)
Poultry	0.996 (0.991,1.002)	0.996 (0.991,1.002)	0.997 (0.991,1.002)
Offal	1.001 (0.996,1.005)	1.002 (0.997,1.007)	1.002 (0.997,1.007)
Seafood	1.001 (1.000,1.002)	1.001 (1.000,1.002)	1.001 (1.000,1.002)
Egg	0.999 (0.997,1.001)	0.999 (0.996,1.001)	0.999 (0.997,1.001)
Soybean products	1.000 (0.999,1.001)	1.000 (0.998,1.000)	0.999 (0.998,1.001)
Vegetables	1.000 (0.999,1.000)	1.000 (0.999,1.000)	0.999 (0.999,1.000)
Milk or Milk products	0.999 (0.998,1.000)	0.998 (0.997,0.999)	0.998 (0.997,0.999)
Fruits	0.999 (0.998,1.000)	0.999 (0.998,1.001)	0.999 (0.998,0.100)
Nuts	1.000 (0.997.1.004)	1.000 (0.996,1.003)	1.001 (0.997,1.004)
Alcohol beverages	1.000 (1.000,1.001)	1.000 (1.000,1.001)	1.000 (1.000,1.002)
Beverages	0.995 (0.990,1.000)	0.997 (0.992,1.002)	0.997 (0.992,1.002)
Diagnosed DM			
Staple food	0.999 (0.998,0.999)	0.999 (0.998,1.000)	0.999 (0.998,1.000)
Red meat	1.002 (1.000,1.003)	1.002 (1.001,1.003)	1.002 (1.000,1.003)
Poultry	1.000 (0.993,1.007)	1.000 (0.993,1.007)	0.999 (0.990,1.007)
Offal	1.002 (0.996,1.008)	1.003 (0.996,1.010)	1.002 (0.994,1.009)
Seafood	0.998 (0.996,1.000)	0.998 (0.996,1000)	0.999 (0.997,1.001)
Egg	1.000 (0.997,1.003)	0.999 (0.996,1.003)	0.999 (0.995,1.002)
Soybean products	1.003 (1.002,1.004)	1.002 (1.000,1.003)	1.000 (1.000,1.003)
Vegetables	1.000 (1.000,1.001)	1.000 (1.000,1.001)	1.000 (1.000,1.001)
Milk or Milk products	1.000 (1.000,1.000)	1.000 (1.000,1.000)	1.000 (1.000,1.000)
Fruits	0.996 (0.994,0.998)	0.997 (0.995,0.999)	0.996 (0.994,0.998)
Nuts	1.002 (0.997,1.007)	1.001 (0.996,1.006)	1.000 (0.999,1.001)
Alcohol beverages	1.000 (0.999,1.001)	1.000 (1.000,1.001)	0.989 (0.977,1.002)
Beverages	0.991 (0.980,1.002)	0.993 (0.983,1.004)	1.004 (1.000,1.009)

[†]Crude: unadjusted.

[‡]Model 1 was adjusted for age and sex.

[§]Model 2 was adjusted for age, sex, educational attainment, marital status, region, personal monthly income, family history of DM, occupational physical activity, smoking, hypertension, BMI, TG and total energy intake.