Greater Adherence to Dietary Guidelines were Associated with Lower Risk of Cardiovascular Diseases in Chinese Patients with Type 2 Diabetes: A Case-Control Study

Shang-Ling Wu
The First Affiliated Hospital of Sun Yat-sen University

Yan-Bin Ye (yeyanbin@mail.sysu.edu.cn)
The First Affiliated Hospital of Sun Yat-sen University

Long-Yun Peng
The First Affiliated Hospital of Sun Yat-sen University

Yu-Ming Chen
Sun Yat-sen University

Fang-Fang Zeng
Jinan University

Shu-Yu Zhuo
The First Affiliated Hospital of Sun Yat-sen University

Yan-Bing Li
The First Affiliated Hospital of Chongqing Medical University

Wei Lu
The First Affiliated Hospital of Sun Yat-sen University

Pei-Yan Chen
The First Affiliated Hospital of Sun Yat-sen University

Hai-Yan Mai
The First Affiliated Hospital of Sun Yat-sen University

Shi Fang
The First Affiliated Hospital of Sun Yat-sen University

Yi Sui
The First Affiliated Hospital of Sun Yat-sen University

Pei-Shan Ruan
The First Affiliated Hospital of Sun Yat-sen University

Research

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Abstract

Background The evidence regarding the impact of the healthy eating index on the risk of cardiovascular events among patients with type 2 diabetes (T2D) is limited. To examine the associations of adherence to the Chinese and American dietary guidelines and the risk of cardiovascular disease (CVD) among Chinese individuals with T2D.

Methods This 1:1 matched case-control study included 419 enrolled pairs hospital-based CVD cases and controls who were matched by age and sex, in Guangdong province, China, all of whom had T2D. A structured questionnaire and a 79-item food-frequency questionnaire was used to collect general information and dietary intake information. Diet quality scores were calculated according to the Chinese Healthy Eating Index (CHEI) and the Healthy Eating Index-2015 (HEI-2015).

Results After adjustment for various confounding factors, the higher diet quality scores on the CHEI and HEI-2015 showed a significant association with a lower risk of CVD. The odds ratios (95% confidence interval) per 5-score increment were 0.88(0.83,0.92) in the CHEI and 0.80(0.74,0.88) in the HEI-2015, respectively. In stratified analyses, the protective associations remained significant in the subgroups of sex, smoking status, tea-drinking, hypertension state, dyslipidemia state, BMI, and T2D duration, but not among the drinkers in CHEI.

Conclusion Greater adherence to the most recent Chinese or American dietary guidelines were associated with a lower risk of CVD incidents among Chinese patients with T2D.

1. Introduction

Type 2 diabetes (T2D) is a worrying global epidemic and is of particular concern in China [1]. The leading cause of death in T2D remains cardiovascular disease (CVD) and hyperglycemia is associated with increased cardiovascular risk [2]. Several studies have shown that the patients with T2D had a 2- to 4-fold greater risk of developing CVD than those of nondiabetics [3]. It is momentous to identify cost-effective strategies for the prevention of cardiovascular complications due to diabetes.

Apart from pharmacological treatment, dietary modification is a fundamental therapy for self-management of diabetes [4]. Previous studies have consistently reported an inverse association between the risk of CVD events and the consumption of individual food items such as fruit (Aune *et al.*, 2017), vegetables [6], whole grains [7], seafood [8], whereas unprocessed red/processed meat [9] and salt [10] are positively associated. By thinking about the multiple dietary exposures' complexity and interrelations, overall dietary pattern analysis, which involves series methods to assess diets comprehensively, might be more informative about the role of diet for the etiology of diet-related diseases than single food item analysis [11].

Among these methods, diet quality indices developed on the strength of healthy dietary recommendations and available evidence of the diseases are design to assess compliance with dietary

guidelines [12]. Substantial indices have been developed to evaluate integral dietary quality according to various dietary guidelines, as indicated by e.g., the Healthy Eating Index (HEI), the Mediterranean Diet Quality Index (MDQI), the alternate Healthy Eating Index (aHEI), and The Dietary Guidelines Index (DGI) [13]. Many studies [14–16] have implied that higher overall diet scores significantly reduce the risk of cardiovascular events in general populations, but the evidence regarding the effect of diet quality indices following a diabetes diagnosis on the risk of subsequent incident of CVD is limited, particularly in the Chinese population. It is well known that the diet recommended for diabetic patients varies from that of general healthy populations, therefore it is necessary to explore the dietary patterns which would be a benefit for the prevention of the complications of diabetes mellitus.

In the current study, we thus investigated the associations between two diet quality indexes, the Chinese Healthy Eating Index (CHEI) [17] and the latest version of the HEI (HEI-2015) [18], which reflects the 2016 Dietary Guidelines for the Chinese population [19] and the 2015–2020 Dietary Guidelines for the American population [20], respectively, and the risk regarding CVD among patients with T2D participating in a 1:1 matched case-control study undertaken in South China. We hope to provide some additional information to the guideline development for T2D.

2. Methods

2.1. Study Population

This case-control study was conducted among patients with existing T2D at the Endocrinology Department, the Neurology Department, and the Cardiology Department of The First Affiliated Hospital of Sun Yat-sen University, in Guangdong Province, China, from March 2013 to September 2015. Participants with previously diagnosed T2D, aged between 30 to 85 years, natives of Guangdong Province, or have lived in Guangdong for at least five years, and with a history at least 2 years of T2D were considered eligible for inclusion in the study. T2D was defined based on American Diabetes Association criteria (fasting plasma glucose > 7.0 mmol L^{-1} or 2-h plasma glucose > 11.1 mmol L^{-1}, or both) [21]; or medication treatment. We excluded participants with (1) confirmed type-1 diabetes, gestational diabetes mellitus ($n = 20$); (2) previous history of cancer, hepatic disease, renal disease, autoimmune disorders, diabetic retinopathy, and congenital heart disease ($n = 182$); (3) physical disability and disturbance of consciousness ($n = 24$); (4) significant changes in dietary habits or routine activities over the previous year ($n = 185$); (5) incomplete dietary assessment (≥ 10% missing values) or an implausible intake of total daily energy (< 700 or > 4200 kcal per day for males, < 500 or > 3500 kcal per day for females [$n = 11$]); and (6) refusal of participate in the study ($n = 39$).

To conduct a case-control study, only patients with a new (diagnosed within 2 weeks) diagnosis of CVD at a date later than the T2D diagnosis were included in the case population. CVD were defined as nonfatal acute myocardial infarction, hospitalized unstable angina, and nonfatal stroke. Nonfatal myocardial infarction [22] and hospitalized unstable [23] angina was diagnosed according to the China Society of Cardiology of Chinese Medical Association criteria, including typical symptoms, elevated

cardiac enzyme levels, and electrocardiographic findings. Nonfatal stroke was ascertained based on the national criteria, according to evidence of neurological deficits with sudden or rapid onset which persisted for a minimum of 24 hours [24]. The control group included patients with T2D who never had a self-reported CVD incident, exhibited no symptoms of cardiac involvement, had normal EKG levels, and had negative exercise tests. Finally, 419 eligible cases and 419 T2D controls, with and without CVD, frequency-matched by sex and age (± 5 years), were included in the current study. All participants provided written informed consent, and the research protocol was approved by the Ethics Committee of The First Affiliated Hospital of Sun Yat-sen University (no. [2017]019).

2.2 Data Collection

Apart from hospital documented data (e.g., clinical characteristics and clinical examinations) for cases, the same questionnaires were used to collect general and dietary factors information during the 12 months prior to diagnosis (for the cases) or interview (for the controls). All of the participants were blind to the study hypothesis. In this study, both cases and controls completed a structured questionnaire via a face-to-face interview by a well-trained dietitian. We collected information regarding (1) socio-demographic characteristics (e.g., age, sex, education level); (2) lifestyles (e.g., tobacco smoking, alcohol consumption, and tea-drinking); (3) habitual dietary consumption during the one year prior to diagnosis (for the cases) or interview (for the controls); (4) history of chronic diseases and medication use (e.g., hypertension, dyslipidemia, insulin use, oral hypoglycemic use); and (5) physical activity. Education was grouped into three levels: primary school or below, middle or high school, and college or above. Participants who had been smoking at least one cigarette per day or drinking alcohol once a week continuously for at least six months were defined as smokers or alcohol drinkers. Tea drinkers were defined as individuals who drank tea at least twice a week. Physical activity was calculated using a 19-item questionnaire by calculating the products of the time spent on a variety of activities (e.g., work, transportation, housework, leisure sedentary activity, and physical exercise) with the mean metabolic equivalent (MET) for that activity [25]. Anthropometric data including weight (kg) and height (m) were ascertained using standard procedures and measuring equipment by trained personnel. Body mass index (BMI, kg/m^2) was also calculated. Participants whose mean systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg and/or in whom anti-hypertensive drug use were defined as hypertension [26]. Individuals whose cholesterol level was ≥ 200 mg/dL, a low-density lipoprotein cholesterol level of ≥ 130 mg/dL, a high-density lipoprotein cholesterol level of < 40 mg/dL, or triglyceride level of ≥ 160 mg/dL or who were taking lipid-lowering medications was defined as dyslipidemia according to the China Atherosclerosis Society guidelines [27].

2.3 Dietary Assessment

A validated 79-item semiquantitative, paper-based, food-frequency questionnaire (FFQ) was used to collect dietary information [28]. For each food item, there were five possible frequencies (i.e., never, per year, per month, per week, and per day) and two predefined amounts of food consumption (i.e., servings or portion sizes) were recorded according to the choice of the participants during the previous year. We provided photographs of generic foods and standard portion sizes to help the participants estimate the

amount of food they had usually ingested. The selected choice for each food was then converted to grams per day. Daily food and nutrient intakes were transformed into standard portions according to the 2016 Dietary Guidelines for the Chinese and the 2013–2014 Food Patterns Equivalents Database, respectively [17, 29]. Daily dietary intakes of nutrients and total energy were calculated based on the Chinese Food Composition Table, 2009 [30]. Accounting for the information of salt ingestion, the detailed intake of salt was not collected in the FFQ, and we thus appointed a score to reflect a participants' sodium consumption according to taste preference (i.e., very salty, salty, moderate, mild, very mild) ranging from 0 to 10 by 2.5.

2.3.1 Chinese Healthy Eating Index (CHEI)

The CHEI [17] is the first instrument in China to assess the overall diet quality adherence to the updated Dietary Guidelines for Chinese (DGC-2016) [19]. The total score of the CHEI ranges from 0 to 100, with 100 being the perfect adherence and 0 being nonadherence. The CHEI score consists of 17 components including 13 adequacy and 5 moderation food groups. Total grains (0–5 points), whole grains and mixed beans (0–5 points), tubers (0–5 points), total vegetables (0–5 points), dark vegetables (0–5 points), dairy (0–5 points), soybeans (0–5 points), fish and seafood (0–5 points), poultry (0–5 points), eggs (0–5 points), seeds and nuts (0–5 points), and fruit (0–10 points) were adequacy components, representing dietary elements that are encouraged, and higher intake reflect higher scores. Red meat (0–5 points), cooking oils (0–10 points), sodium (0–10 points), added sugars (0–5 points), and alcohol (0–5 points) were moderation components, which are dietary elements that are recommended to be limited, and lower ingestion reflected higher scores. Intermediate intake of every component was calculated proportionally. A score is given to each component and a total CHEI score is generated by calculating each component score. Each component is adjusted for total energy using the density method (per kilocalorie), except for sugar (percentage of energy) and alcohol (absolute consumptions). Higher overall CHEI scores signify better alignment with the latest Dietary Guidelines for the Chinese, and the validity and reliability of the CHEI have been examined explicitly [31]. Details are listed in Supplemental Table S1.

2.3.2 Healthy eating index (HEI)-2015

The HEI-2015 score [18], ranging from 0-100 possible points, which was exploited by the United States Department of Agriculture (USDA), was created to evaluate adherence to the 2015–2020 Dietary Guidelines for Americans (2015–2020 DGA) [20] and consists of 13 components including 9 adequacy and 4 moderation components, that were scored based on energy-adjusted food and nutrient intakes. The 3 adequacy components (i.e., whole grains, dairy, and fatty acids) are worth 0 to 10 points each, with 10 for highest and 0 for the lowest consumption. The remaining 6 adequacy components (i.e., total fruits, whole fruits, total vegetables, greens and beans, total protein foods, and seafood and plant proteins) are worth 0 to 5 points each, with 5 for the highest and 0 for the lowest ingestion. The 4 moderation components (i.e., refined grains, sodium, added sugars, and saturated fats) are recommended to be limited, and the lowest consumption of these dietary elements was scored as 10, while the highest scored as 0. Scores are counted proportionately according to the consumption between the minimum and

maximum standards. A higher score indicates greater adherence to DGA recommendations and a better diet quality [18], and the HEI-2015 has good validity and reliability for assessing the diet quality relative to the updated Dietary Guidelines for Americans [32]. Details are listed in Supplemental Table S1.

2.4 Statistical analysis

All analyses were performed for males and females combined, except for analyses stratified by sex. For group comparisons, t-tests were used for the continuous variables with a normal distribution; Wilcoxon signed ranks tests were used for the others with a skewed distribution; and Chi square tests were used for the categorical variables, where appropriate. The scores of each component of the CHEI and HEI-2015 were divided into four groups, classified according to the range of percentage of full scores ([individual score/full score] 100%): 0% (0 point), 0.1–49.9%, 50-99.9% and 100% (full points), with corresponding value of 0, (0–50% of maximum score), (50% of maximum score), and maximum score, respectively. For the full scores of 5, the cutoffs were 0, 0.1–2.4, 2.5–4.9, and 5.0, and for the full scores of 10, the cutoffs were 0, 0.1–4.9, 5-9.9, and 10.0. CVD odds ratios (ORs) and 95% confidence intervals (CIs) were estimated using conditional logistic regression models, and we served the scores as continuous variables (per 5-point increments). Crude OR was calculated in the univariate model; and multivariable model was adjusted for age, BMI, marital status, physical activity, education level, smoking status, alcohol consumption, tea-drinking status, hypertension status, dyslipidemia status, T2D duration, antidiabetic medication using status, and non-alcohol energy intake. We also repeated all analyses with unconditional logistic regression modeling because if perfect matching were not possible, undertaking a strict matched analysis would result in the loss of relevant information[33]. Stratified analyses were conducted by sex, BMI (< 24 *vs.* ≥24 kg/m^2), smoking status (yes or no), alcohol consumption (yes or no), tea-drinking (yes or no), hypertension (yes or no), dyslipidemia (yes or no), T2D duration (< 5 *vs.* ≥5 years) and to calculate the multiplicative interactions by including each interaction item. All undertaken analyses were conducted using SPSS 23.0 (IBM Corp., Armonk, NY, USA) and $p < 0.05$ was considered statistically significant.

3. Results

3.1 Characteristics of the participants

The selected characteristics of the 419 pairs (235 male pairs and 184 female pairs) of CVD cases and matched controls are shown in Table 1. The mean age was 61.13 years in the cases and 62.08 years in the controls. Compared with controls, the cases had significantly lower mean CHEI scores (65.34 ± 9.48 *vs.* 71.31 ± 9.05) and HEI-2015 scores (54.03 ± 6.09 *vs.* 57.77 ± 6.79). All *p*-values were < 0.05. The cases had lower physical activity, education level, T2D duration, and a lower proportion of tea-drinking and antidiabetic medication use, but they had a higher BMI, and there was a higher proportion of hypertension than in that of the controls. The CHEI scores were significantly correlated with the HEI-2015 scores (Spearman's $r = 0.724$; $p < 0.001$).

Table 1
Characteristics of the study participants.

Variable	Control (n = 419)	Case (n = 419)	p-value
Age (y)	62.1(9.5)	62.1 (9.7)	0.940
Sex, n (%)			–
Female	184(43.9)	184(43.9)	
Male	235(56.1)	235(56.1)	
BMI (kg/m^2)	23.79(3.47)	24.37(3.26)	**0.013**
Smoker (%)			0.282
Yes	115(27.4)	131(31.3)	
No	304(72.6)	287(68.7)	
Alcohol consumption, n (%)			0.582
Yes	370(88.3)	375(89.5)	
No	49(11.7)	44(10.5)	
Tea drinking, n (%)	220(52.5)	188(44.9)	**0.027**
Physical activity (MET-h/d)	26.05(24.38, 28.46)	25.56(23.93, 27.65)	**0.015**
Marital status, married, n (%)	401(95.7)	396(94.5)	0.423
Education level, n (%)			**0.002**
<Middle school	148(35.4)	163(39.4)	
Middle/High school	102(24.4)	132(31.9)	
≥College	168(40.2)	119(28.7)	
Hypertension, n (%)	206(49.5)	313(75.2)	**< 0.001**
Dyslipidemia, n (%)	230(57.1)	234(61.7)	0.184

Abbreviations: BMI, body mass index; MET-h/day, Metabolic equivalent hours per day; CHEI, Chinese Healthy Eating Index; HEI-2015, Healthy Eating Index 2015.

[a] Values are mean SD or median (P_{25}, P_{75}), where appropriate.

[b] Total energy intake was dietary energy except for alcohol.

Statistically significant results are bolded.

Variable	Control (*n* = 419)	Case (*n* = 419)	*p*-value
T2D duration (y)	8.96(6.74)	7.1(6.21)	**< 0.001**
Antidiabetic medication use, n (%)	408(99.5)	375(97.9)	**0.043**
CHEI	71.31(9.05)	65.34(9.48)	**< 0.001**
HEI-2015	57.77(6.79)	54.03(6.09)	**< 0.001**
Total Energy (kcal/d) [b]	1439.00(1241.70, 1703.70)	1393.40(1187.10, 1696.15)	0.160
Abbreviations: BMI, body mass index; MET-h/day, Metabolic equivalent hours per day; CHEI, Chinese Healthy Eating Index; HEI-2015, Healthy Eating Index 2015.			
[a] Values are mean SD or median (P_{25}, P_{75}), where appropriate.			
[b] Total energy intake was dietary energy except for alcohol.			
Statistically significant results are bolded.			

3.2 Participants in the Percentage distribution for each component

The proportion in the percentage distribution of participants for the CHEI (A) and the HEI-2015 (B) component scores of each item are shown in Fig. 1. More than 50% of individuals achieved the recommendation (obtain the maximum points) of components for total grains, total vegetable, dark vegetable, fish and seafood, poultry, seeds and nuts, added sugars, and alcohol in the CHEI; and for total vegetable, greens and beans, total protein foods, seafood and plant proteins, added sugars, saturated fats in the HEI-2015. However, whole grains and mixed beans (65.5%), dairy (71.9%), soybeans (59.8%) and fruits (78.6%) in the CHEI, and total fruits (80.7%), whole fruits (53.6%), whole grains (87.9%), dairy (91.4%) and refined grains (94.9%) in the HEI-2015 were components that had a relatively serious degree of deficiency intake (did not meet 50% of the recommendations) among the components. The score differences in the 10 components of the CHEI and 5 components of the HEI-2015 between cases and controls are all significant (all $p < 0.05$). The control group scored better than the case group in food groups of whole grains and mix beans, tubers, total vegetables, dark vegetables, dairy, soybeans, and eggs in the CHEI, and food groups of total fruits, whole fruits, total vegetables, whole grains, and dairy in the HEI-2015.

3.3 Total risk score and stratified analysis.

Associations between the CHEI and HEI-2015 scores and CVD risk are shown in Table 2. In the univariate model, participants with lower CHEI and HEI-2015 scores had a significantly increased risk of CVD (both $p < 0.05$). In the multivariable model, the risk persisted, and the ORs (95% CIs) were 0.88(0.83,0.92) and 0.80(0.74,0.88) for per 5-point increment of CHEI and HEI-2015, respectively. In a stratified analysis of the subjects, the protective associations between the CHEI and HEI-2015 scores and CVD risk did not materially change according to the subgroups of sex, smoking status, tea-drinking, hypertension state, dyslipidemia state, BMI, and T2D duration, but not among the alcohol drinkers in CHEI. The analyses were repeated with unconditional logistic regression modeling and not substantially different from the conditional logistic regression modeling for all comparisons (data not shown).

Table 2
ORs (95% CIs) of CVD for per 5-point increment of CHEI and HEI-2015 stratified by selected factors.

	n (cases/ controls)	Crude OR (95% CI)	Multivariable- adjusted [a] OR (95% CI)	*p*-interaction
CHEI				
Total scored	419/419	0.86(0.82,0.90)	0.88(0.83,0.92)	
Sex				0.088
Female	184/184	0.89(0.83,0.96)	0.89(0.83,0.96)	
Male	235/235	0.82(0.77,0.87)	0.85(0.79,0.92)	
BMI, kg/m^2				0.327
≥ 24	198/184	0.89(0.82,0.95)	0.91(0.84,0.98)	
< 24	221/235	0.84(0.79,0.89)	0.86(0.80,0.92)	
Smoker				0.541
Yes	131/115	0.83(0.76,0.90)	0.87(0.79,0.96)	
No	287/304	0.87(0.82,0.92)	0.88(0.83,0.94)	
Alcohol consumption				0.513
Yes	44/49	0.89(0.74,1.07)	0.94(0.76,1.16)	
No	375/370	0.85(0.81,0.90)	0.87(0.83,0.92)	
Tea-drinking				0.471
Yes	188/220	0.84(0.78,0.90)	0.86(0.80,0.93)	
No	231/199	0.87(0.82,0.93)	0.89(0.82,0.95)	
Hypertension				0.110
Yes	313/206	0.90(0.85,0.95)	0.92(0.86,0.98)	
No	103/210	0.79(0.72,0.87)	0.79(0.72,0.88)	
Dyslipidemia				0.646

Abbreviations: CHEI, Chinese Healthy Eating Index; HEI-2015, Healthy Eating Index 2015; ORs, Odds ratios, CI, Confidence Interval.

[a] Adjusted for age, body mass index, marital status, physical activity, education level, smoker status, alcohol consumption, tea-drinking status, hypertension status, dyslipidemia status, T2D duration, antidiabetic medication using status, and non-alcohol energy.

	n (cases/	Crude	Multivariable- adjusted [a]	*p*-interaction
Yes	234/230	0.88(0.83,0.94)	0.90(0.83,0.96)	
No	145/173	0.81(0.75,0.88)	0.83(0.75,0.92)	
T2D duration, y				0.922
≥5	227/269	0.86(0.81,0.92)	0.87(0.80,0.93)	
<5	192/150	0.86(0.80,0.92)	0.87(0.81,0.94)	
HEI-2015				
Total scored	419/419	0.79(0.73,0.86)	0.80(0.74,0.88)	
Sex				0.107
Female	184/184	0.83(0.74,0.94)	0.87(0.76,0.98)	
Male	235/235	0.72(0.64,0.81)	0.76(0.67,0.86)	
BMI, kg/m^2				0.116
≥ 24	198/184	0.84(0.74,0.94)	0.86(0.76,0.98)	
< 24	221/235	0.76(0.68,0.84)	0.76(0.67,0.86)	
Smoker				0.465
Yes	131/115	0.73(0.62,0.86)	0.77(0.65,0.92)	
No	287/304	0.81(0.73,0.89)	0.82(0.74,0.91)	
Alcohol consumption				0.976
Yes	44/49	0.74(0.55,1.00)	0.71(0.49,1.04)	
No	375/370	0.79(0.73,0.86)	0.81(0.74,0.88)	
Tea-drinking				0.610
Yes	188/220	0.77(0.69,0.87)	0.80(0.70,0.91)	
No	231/199	0.80(0.72,0.89)	0.81(0.72,0.91)	
Hypertension				0.569

Abbreviations: CHEI, Chinese Healthy Eating Index; HEI-2015, Healthy Eating Index 2015; ORs, Odds ratios, CI, Confidence Interval.

[a] Adjusted for age, body mass index, marital status, physical activity, education level, smoker status, alcohol consumption, tea-drinking status, hypertension status, dyslipidemia status, T2D duration, antidiabetic medication using status, and non-alcohol energy.

	n (cases/	Crude	Multivariable- adjusted [a]	*p*-interaction
Yes	313/206	0.86(0.78,0.95)	0.88(0.79,0.98)	
No	103/210	0.71(0.61,0.84)	0.71(0.60,0.84)	
Dyslipidemia				0.615
Yes	234/230	0.83(0.75,0.93)	0.84(0.75,0.94)	
No	145/173	0.75(0.65,0.86)	0.76(0.65,0.89)	
T2D duration, y				0.267
≥5	227/269	0.83(0.75,0.93)	0.84(0.74,0.95)	
<5	192/150	0.76(0.67,0.85)	0.76(0.67,0.86)	

Abbreviations: CHEI, Chinese Healthy Eating Index; HEI-2015, Healthy Eating Index 2015; ORs, Odds ratios, CI, Confidence Interval.

[a] Adjusted for age, body mass index, marital status, physical activity, education level, smoker status, alcohol consumption, tea-drinking status, hypertension status, dyslipidemia status, T2D duration, antidiabetic medication using status, and non-alcohol energy.

3.4 Association of each component score with CVD

Figure 2 presents the ORs and 95% CIs of each component score of CHEI (A) and HEI-2015 (B) for CVD risk between the case and control groups. Compared with the case group, lower risk of CVD was associated with higher scores for the following components: whole grains and mixed beans (OR, 0.92; 95% CI 0.87, 0.97), total vegetables (OR, 0.86; 95% CI 0.77, 0.97), dark vegetables (OR, 0.89; 95% CI 0.80, 0.98), dairy (OR, 0.91; 95% CI 0.86, 0.96), eggs (OR, 0.86; 95% CI 0.92, 0.98), fruit (OR, 0.94; 95% CI 0.90, 0.97) and sodium (OR, 0.94; 95% CI 0.89, 0.99) in the CHEI; total fruits(OR, 0.87; 95% CI 0.81, 0.95), whole fruits (OR, 0.90; 95% CI 0.85, 0.96), whole grains (OR, 0.95; 95% CI 0.91, 0.98), dairy (OR, 0.91; 95% CI 0.86, 0.97), and sodium (OR, 0.94; 95% CI 0.89, 0.99) in the HEI-2015.

4. Discussion

In this 1:1 case-control study with 419 pairs hospital-based CVD cases and T2D controls conducted in South China, we found a higher score between the CHEI or HEI-2015 after diabetes diagnosis, reflecting greater alignment with the latest and authoritative dietary guidelines for the Chinese or the Americans, and had strong favorable associations with lower risk of cardiovascular outcomes among Chinese adults with diabetes.

Several studies and meta-analyses [14–16, 34, 35] have consistently shown that high diet quality, as assessed by HEI, AHEI, DASH, and Med score is inversely associated with the risk of CVD incidence in the general population. In the US Women's Health study which included 25,994 women (followed-up for 12 years), the consumption of a diet with a high baseline Med score may reduce the risk of cardiovascular events by one-fourth when comparing the upper (Med score 6–9) and lower (Med score ≤ 3) after adjustment for cardiovascular disease risk factors [16]. Similar findings were seen in 1867 middle-aged men from the Caerphilly Prospective Study, in which diets of the highest quality, as assessed by DASH and AHEI-2010 scores, resulted in a significant reduction in the incidence risk of CVD and stroke, but not coronary heart disease, with multivariable adjusted hazard ratios ranging from 0.61 to 0.81 in the highest (*vs.* lowest) tertiles [14]. Data from the prospective Singapore Chinese Health study showed that the AHEI-2010, which are strongly correlated with the HEI-2010, had an inverse association with the risk of fatal and nonfatal acute myocardial infarction among women and men (p trend, 0.009 and 0.002, respectively) [15]. However, significant protective associations have only been shown between nut consumption [36] or overall healthy lifestyle [37] and the risk of CVD among diabetes patients in previous studies. Few studies have examined the risk of CVD regarding national dietary guidelines, particularly among persons with diabetes mellitus. It is unknown how to eat properly to prevent cardiovascular events in diabetic patients who are at high-risk of CVD. The finding of this study is in accordance with observational studies [38, 39] conducted in individuals with diabetes, showing a significant protective effect of intermediate cardiovascular risk factors profile, as indicated by e.g., fasting blood glucose, triglycerides, and systolic blood pressure, in patients who adhered mostly to the HEI-2010 (Daneshzad *et al.*, 2019) or Mediterranean diet [39], yet an absence of data on CVD incident outcomes in these studies does not allow comparisons with our results. In general, our detections and existing evidence imply that aligning with a healthy dietary pattern after a diabetes diagnosis can momentously contribute to the prevention of cardiovascular complications among patients with T2D.

We also explored the relationship between each food group component scores for participants of CHEI and HEI-2015 and the achievement of treatment targets for participants' risks. The beneficial effects of high-quality dietary scores may reflect the synergistic effects of diverse foods characterized by a higher intake of vegetables, fruit, whole grains, soybeans and dairy, and a moderate intake of cooking oils, sodium and red meat. Research has shown that whole grains and vegetables are primary sources of dietary fiber conducive to furthering hyperglycemia and improving dyslipidemia owing to the low glycemic index and anticholesterolemic actions [40]. Furthermore, micronutrients including minerals, vitamins, and phytochemicals are rich sources of these foods, all of which include insulin-sensitizing properties, are anti-inflammatory, reduce hypercoagulability, and regulate metabolic and antioxidant pathways to improve macro- and micro-vascular status [41]. The healthy dietary pattern mainly lies in its combined effect among all types of foods and nutrients instead of on any single component. Nonetheless, because our study was an observational study, this association should be interpreted with caution, as future biological mechanical research and possible interventional studies are needed to further illustrate potential mechanisms in the prevention of cardiovascular events among patients with T2D.

In alcohol consumption-stratified analyses, the favorable association between CHEI and cardiovascular events remained significant in non-drinkers but not in drinkers. Taking into consideration the number of participants who drank alcohol, this may be just due to a low statistical power in this subgroup. In addition, the interaction with alcohol consumption was not statistically significant, which does not speak for a different association among drinkers and non-drinkers. Additionally, we further assessed the CHEI score after removing alcohol consumption from the categories, with the results being similar.

To our knowledge, our study assesses T2D patients' CVD risk associated with adherence to DGC-2016 and/or 2015–2020 DGA for the first time in a case-control design. Moreover, we only included newly diagnosed CVD patients with comparable age and sex to minimize recall bias. Furthermore, we excluded the participants with substantial changes in diet during the prior one year to ensure the representativeness of the habitual diet before diagnosis or interview. Additionally, multiple potential covariates, including explicit risk factors of CVD (i.e. hypertension status, dyslipidemia status, antidiabetic medication use) were included in the analyses for reducing residual confounding. Information bias was also further minimized because the participants were blinded to the hypothesis.

Nevertheless, several limitations of the study should be acknowledged. First, reverse causality could not be fully ruled out in the case-control design because the dietary intake information was assessed after the diagnosis of CVD. To minimize this possibility, we recruited only new cases (diagnosed within 2 weeks) into our study and collected the cases' diet information using the FFQ from the past twelve months prior to diagnosis. Second, although the FFQs used in our study were validated and implemented during face-to-face interviews by well-trained dietitians, dietary measurement errors are inevitable [42]. Third, the outcomes for the sodium component should be interpreted with caution because discretionary salt being used in cooking was not accurately captured in our FFQs. As with previous epidemiological studies, it is crude and likely to underestimate the ingestion of dietary sodium consumption assessment by using an FFQ. Finally, prior dietary indexes were derived based on current learning, and the CHEI and HEI-2015, originally directed toward general populations, rather than T2D, to prevent chronic disease.

5. Conclusion

The findings from this case-control study suggest that higher adherence to either Chinese or American dietary guidelines, as reflected in the CHEI and HEI-2015, were similarly associated with a substantially lower risk of CVD among Chinese patients with T2D. Our results further support the current recommendation that patients with diabetes adopt a healthy dietary pattern may be a promising strategy for the prevention of CVD complications. Further studies, especially large prospective studies, are needed to replicate these findings.

Abbreviations

CVD: cardiovascular disease; T2D: type 2 diabetes; CHEI: the Chinese Healthy Eating Index; HEI: the Healthy Eating Index; aHEI: the alternate Healthy Eating Index; MDQI: the Mediterranean Diet Quality

Index; DGI: The Dietary Guidelines Index; MET: metabolic equivalent; BMI: body mass index; FFQ: food-frequency questionnaire; DGC: Dietary Guidelines for Chinese; MPED, MyPyramid Equivalents Database; USDA: the United States Department of Agriculture; DGA: Dietary Guidelines for Americans; OR: odds ratio; CI: confidence interval.

Declarations

Ethical Approval and Consent to participate

All participants provided written informed consent, and the research protocol was approved by the Ethics Committee of The First Affiliated Hospital of Sun Yat-sen University (no. [2017]019)

Consent for publication

All authors of this paper have read and have approved the final submitted version.

Availability of supporting data

Participants' data cannot be shared because of the protection of data privacy.

Competing interests

The authors declare that they have no other conflicts of interest to disclose.

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Authors' contributions

The authors' contributions are as follows: Yan-Bin Ye. and Yu-Ming Chen conceived and designed the study; Long-Yun Peng, Shu-Yu Zhuo, Yan-Bing Li, Wei Lu, Pei-Yan Chen, Hai-Yan Mai, Shi Fang, Yi Sui and Pei-Shan Ruan carried out the study; Shang-Ling Wu analyzed the data, wrote the paper., Shang-Ling Wu, Yan-Bin Yan, and Fang-Fang Zeng revised the final paper; all the authors read and approved the final version of the manuscript.

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Figures

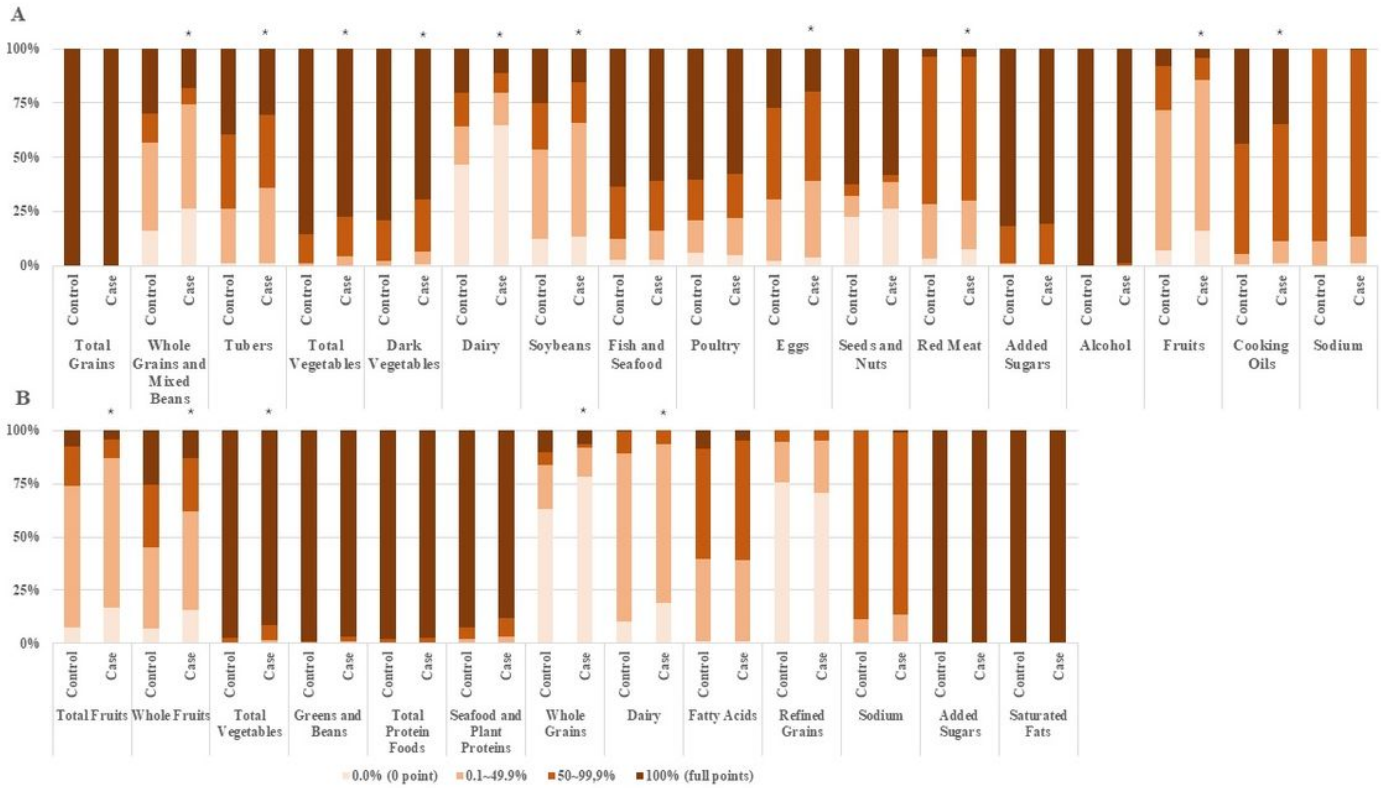
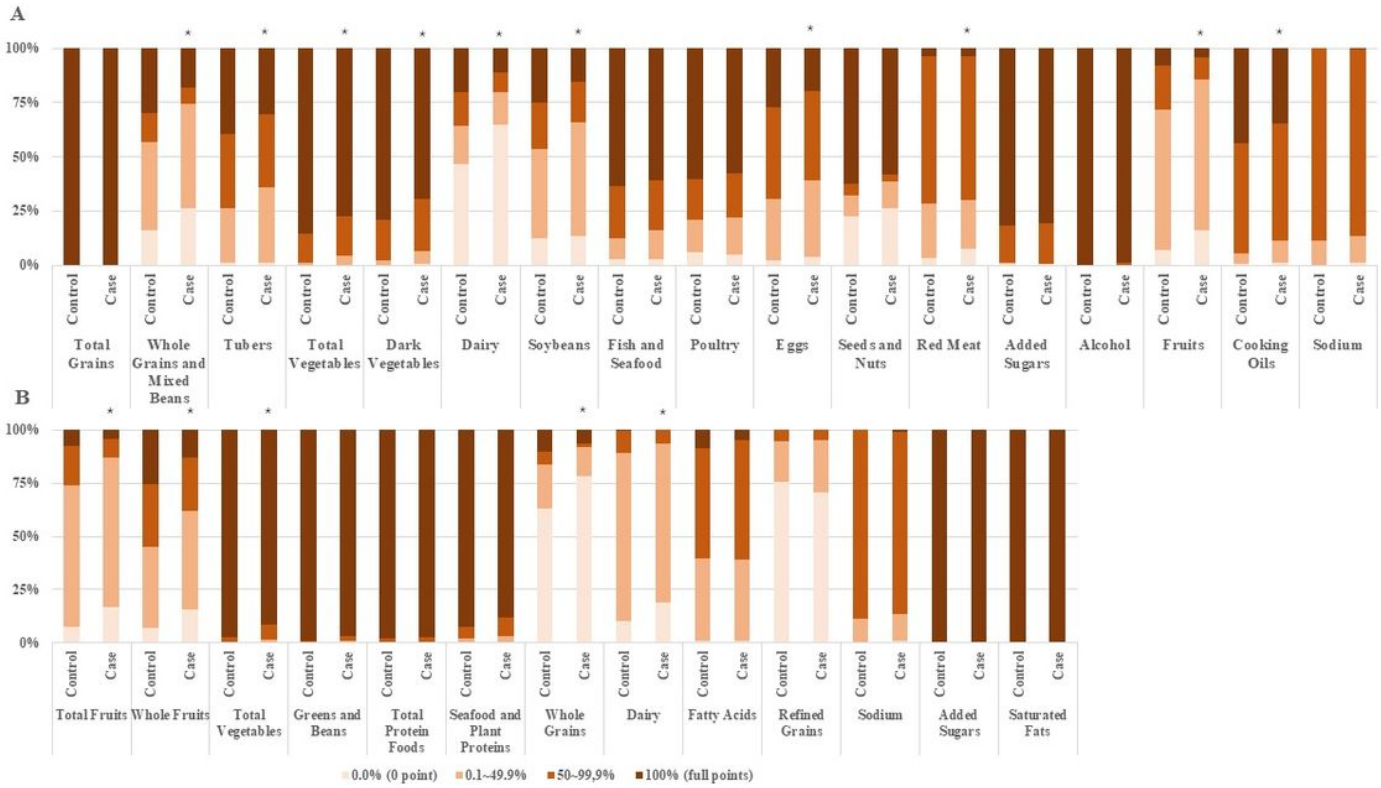


Figure 1

Comparison of the percentage distribution of the cases and controls according to the scores of each item for the CHEI (A) and the HEI-2015 (B). For fruits, sodium, and cooking oils in the CHEI and whole grains, dairy, fatty acids, refined grains, sodium, added sugars, and saturated fats in the HEI-2015, the cutoffs for the four groups are 0, 0.1–4.9, 5.0–9.9, and 10.0. For the remaining components in the CHEI and the HEI-2015, the cutoffs for the four groups are 0, 0.1–2.4, 2.5–4.9, and 5.0. *: $p < 0.05$ (chi-square test).



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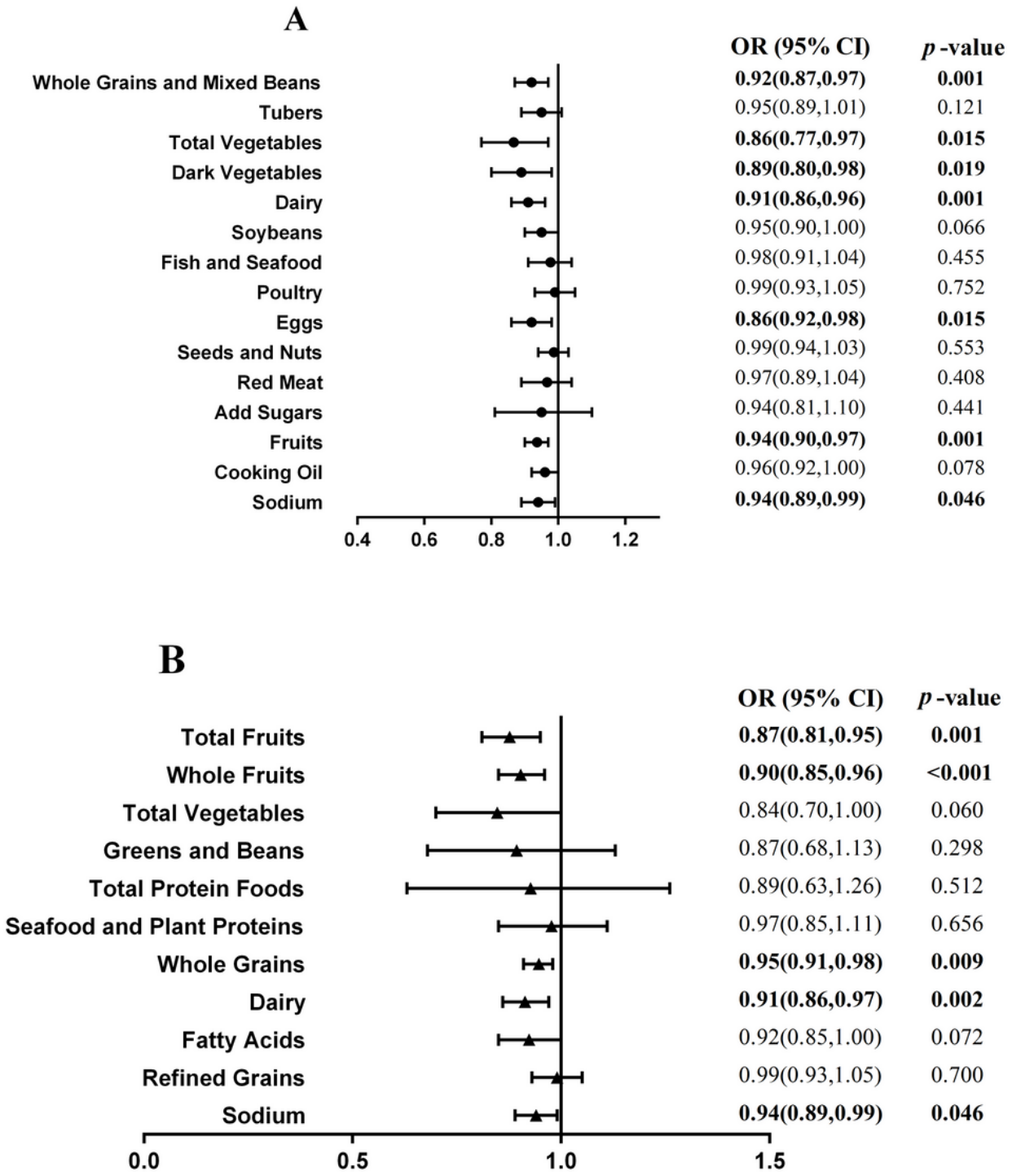

Figure 2

Association of each component score of CHEI (A) and HEI-2015 (B) with cardiovascular complications risk between case and control. ORs were adjusted for age, body mass index, marital status, physical activity, education level, smoker status, alcohol consumption, tea-drinking status, hypertension status, dyslipidemia status, T2D duration, and non-alcohol energy. Fatty acids, A ratio of total unsaturated fatty

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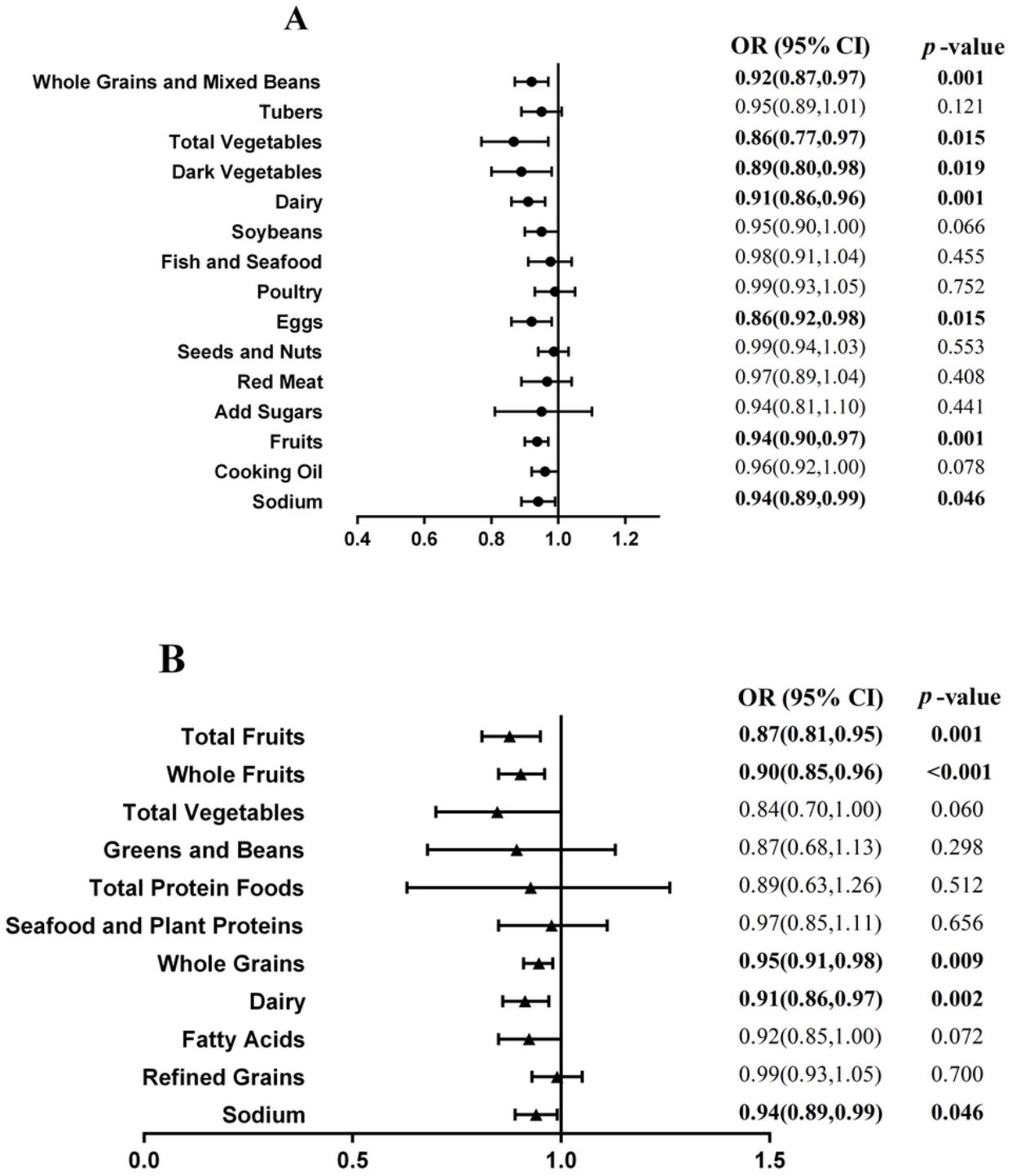

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