Original Article

Association between fruit, vegetable, seafood, and dairy intake and a reduction in the prevalence of type 2 diabetes in Qingdao, China

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Background and Objectives: Fruit, vegetable, seafood, and dairy intake may reduce the risk of type 2 diabetes, but this relationship is unclear. We aimed to examine the associations between fruit, vegetable, seafood, and dairy intake and type 2 diabetes prevalence in a Chinese population. **Methods and Study Design**: A total of 4,343 individuals aged 35-74 years participated in a population-based cross-sectional study in Qingdao, China. The frequency and quantity of fruit, vegetable, seafood, and dairy intake were determined using a standard food frequency questionnaire. Diabetes was classified according to the WHO/IDF 2006 criteria. Logistic regression analysis was employed to estimate odds ratio (OR) for type 2 diabetes in relation to fruit, vegetable, seafood, and dairy intake in a multivariable model. **Results:** The multivariate-adjusted ORs (95% confidence interval) for the presence of type 2 diabetes were 0.68 (0.46-0.98), 0.50 (0.37-0.68), and 0.91 (0.66-1.25), respectively, for the highest versus the lowest groups regarding total fruit and vegetable, fruit or vegetable intake in women. The ORs for type 2 diabetes prevalence regarding the quantity of fruit and vegetable, fruit, and yogurt intake were 0.88 (0.78-0.99), 0.71 (0.61-0.82), and 0.56 (0.32-0.98) in women, but not in men. Seafood consumption was inversely associated with diabetes risk in men, but not in women; the corresponding figures were 0.58 (0.35-0.96) and 0.92 (0.63-1.36), respectively. **Conclusions**: Fruit, vegetable, and yogurt intake in women and seafood intake in men were inversely associated with type 2 diabetes prevalence in this Chinese population. These findings require confirmation in a prospective study.

Key Words: dietary intake, type 2 diabetes, prevalence, adult, Chinese

INTRODUCTION

Diabetes is a major chronic disease, which is predicted to affect approximately 552 million adults worldwide by 2030.[1] Diabetes and its complications impose a heavy economic burden on China.[2] Several clinical trials indicate that dietary modification could delay or prevent the development of diabetes among individuals with impaired glucose regulation.[3] Adequate fruit, vegetable, seafood, and dairy product intake may reduce the risk of diabetes, but the underlying mechanisms are not clear. Researchers have focused on the role of carbohydrates and fiber,[4,5] and a combination of antioxidants and phytochemicals that are found in fruit and vegetables might promote health by combating free radicals, which are associated with the early phase development of some chronic diseases.[6] High intakes of fruit and vegetables have been shown to increase concentrations of plasma carotenoids and vitamin C,[7-9] both of which have antioxidant properties. Additionally, seafood and dairy products are also associated with a reduction of diabetes risk. Considering that Chinese traditional dishes often contain a high amount of fruit and vegetables, along with a high amount of seafood in coastal cities, consuming these types of food could conceivably be an efficient method of delaying or preventing the development of diabetes. However, previous studies on this subject have not been thoroughly conducted in China. Therefore, the purpose of this study was to investigate the association between fruit, vegetable, seafood, and dairy product intake and the prevalence of type 2

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diabetes in a population-based cross-sectional study in Qingdao, China.

MATERIALS AND METHODS

Study population

From April 2009 to December 2011, a population-based cross-sectional survey was conducted in 3 urban districts (Shinan, Shibei, and Sifang) and 3 rural counties (Jiaonan, Huangdao, and Jimo) in Qingdao, China. A stratified, random cluster sampling method was used to recruit a representative sample of those in the general population who had lived in Qingdao for at least 5 years. A total of 7,611 individuals were invited to the survey, and 5,110 attended, with a response rate of 67.1%. After individuals with missing information were excluded, data for 1,641 men and 2,702 women were included in the current study.

Participants were interviewed by trained doctors or nurses at the local survey sites. Anthropometric measurements including height, weight, waist circumference, and blood pressure were conducted. Personal behavioral factors, including smoking habits, alcohol intake, and family history of diabetes were defined, as described elsewhere.[10] Family monthly income was classified into 3 levels: <3,000, 3,000-5,999, and ≥6,000 Chinese Yuan (CNY) (2012 average: 1 USD=6.83 CNY). Educational level was divided into 3 categories: illiterate or elementary school, secondary school, and college or higher education. Physical activity was surveyed using a standardized questionnaire recommended by the Ministry of Health; People's Republic of China.[11] The questionnaire investigated 5 major types of daily physical routines among Chinese adults: walking, housework, leisure time physical activity, bicycling, and occupational physical activity. Participants reported the frequency and duration of each specific physical activity during the past year on a daily, weekly, monthly, or yearly basis, after which the information given was converted into a walking-distance equivalent value according to physical effect. For instance, a 10-minutewalk at a rate of 4 km/his equal to a 1-km walk, and cooking for 13 minutes is also equal to a 1-km walk. Total physical activity was categorized as sedentary or light (≤40-km walk/wk), moderately active (40-70-km walk/wk), or vigorously active (>70-km walk/wk).

After overnight fasting, a fasting plasma glucose (FPG) test and 2-hour 75-g oral glucose tolerance test (OGTT) was performed on participants, except for those that were previously diagnosed with diabetes. Blood samples were collected from the antecubital vein into a vacuum tube containing sodium fluoride. Previously diagnosed diabetes was confirmed by an examiner at the survey site according to prior history of a diabetes diagnosis or antidiabetic treatment. Newly diagnosed diabetes was defined as FPG ≥7.0 mmol/L and/or 2-hour plasma glucose ≥11.1 mmol/L according to the 2006 WHO/IDF diagnostic criteria.[12]

Food frequency questionnaire and 24-hour dietary recall

Habitual diet was estimated using an interviewer-administered, 54-item validated food quantitative frequency questionnaire.[13] Fruit included citrus fruit (eg, tangerines, oranges, and lemons) and other fruit (eg, apples, pears, and grapes). Fresh vegetables included beans (eg, peas and cowpeas; soybeans and dried beans were not included), roots and bulbs of vegetables (eg, carrots and onions), fruit of plants considered vegetables (eg, pumpkins, cucumbers, tomatoes, and eggplants) and stems, leaves, and flower buds of plants (eg, celery, spinach, cabbage, lettuce, and broccoli).[14] Dietary questionnaire data on dairy products were categorized into milk(high- and low-fat dairy combined), milk powder, yogurt, and cheese data. Seafood data were divided into fish and shell-fish data. To calculate the intake of specific foods, a commonly used portion size for each food was specified, and the participants were asked how often, on average, during the previous year they had consumed that amount. In addition, standardized 24-hour dietary recall, including energy from carbohydrates, protein, fat, and alcohol, was assessed according to the China Food Composition Tables.[15]

Statistical analysis

The differences between groups were tested using a general linear model for continuous variables, adjusting for age, and a chi-square test for categorical variables. Logistic regression analysis was performed to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) for type 2 diabetes prevalence, adjusting for age, family history of diabetes, body mass index (BMI), systolic blood pressure, physical activity, educational level, and smoking habits as well as alcohol, fruit and vegetable, red meat, seafood, soft drink, dairy product, soy product, nutrient, tea, and total energy intake. All analyses were performed using SPSS for Windows 18.0.2 (SPSS Inc., Chicago, IL, USA). All p values were based on 2-tailed tests, and statistical significance was set at $p<0.05$.

RESULTS

Among the 4,343 participants, 692 (15.9%) were identified as having type 2 diabetes. The individuals with diabetes were older, had higher blood pressure, BMI, and waist circumference, had a higher proportion of a positive family history of diabetes, and had a lower proportion of vigorous activity compared with those without diabetes (Table 1). The mean daily and 95% CI of fruit and vegetable intakes were 73.3 g (70.2, 76.4) per day and 239 g (231, 246) per day, respectively. For men, the daily average total fruit and vegetable intake was 331 g (317, 345); fruit intake was 64.3 g (59.7, 68.9) per day, and vegetable intake was 267 g (255, 279) per day. For women, the daily average total fruit and vegetable intake was 300 g (289, 311); fruit intake was 78.7 g (74.6, 82.8) per day, and vegetable intake was 221 g (212, 231) per day. No significant difference was observed in the consumption of fruit and vegetables between individuals with and without diabetes, except that the daily average consumption of fruit in women without diabetes was higher than in those with diabetes.

The multivariate-adjusted OR for diabetes prevalence was lower in women who had higher total fruit and vegetable intake than in those who had lower intake, but this finding was not observed in men (Table 2). After we adjusted for conventional factors, the association between diabetes and fruit and vegetable intake was attenuated,

Table1. Characteristics of men and women according to diabetic status

	Men		Women	
	Non-diabetes	Diabetes	Non-Diabetes	Diabetes
N (%)	1366 (83)	275 (17)	2285 (85)	417 (15)
Age (years)	53 (52, 53)	58 (57, 60)***	51 (51, 52)	59 (58,60)***
Body mass index (kg/m^2)	24.4 (24.2, 24.6)	25.4 (24.9, 25.8)***	25.1 (24.9, 25.2)	26.5 (26.1, 26.9)***
Family history of diabetes, n (%)	107 (7.8)	54 (19.6)***	232 (10.2)	79 (18.9)***
24-h energy intake (kcal)	2636 (2542,2729)	2482 (2313, 2650)	2170 (2123,2218)	2009 (1887, 2132)
Systolic blood pressure (mmHg)	133 (132,134)	144 (141,146)***	131 (130, 132)	146 (144, 148)***
Diastolic blood pressure (mmHg)	83.1 (82.5, 84.7)	85.9 (81.5, 87.4)**	81.1 (80.6, 81.6)	85.3 (84.2, 86.5)***
Education, n (%)				
Elementary school/illiterate	453 (33)	110 (40)	989 (43)	245 (59)***
Secondary school	827 (61)	151 (55)	1184 (52)	157 (38)
College or higher education	86 (6)	14 (5)	112 (5)	15 (3)
Family income (CNY/month), n (%)				
<3,000	1038 (80)	200 (76)	1725 (78)	311 (78)
3,000-5,999	200 (15)	45 (17)	364 (17)	72 (18)
≥6,000	58 (5)	19 (7)	112 (5)	17 (4)
Waist circumference (cm)	84.5 (83.9, 85.1)	88.0 (86.7, 89.3)***	82.0 (81.6, 82.4)	87.5 (86.5, 88.5)***
Physically activity level, n (%)				
Sedentary or light	530 (38.8)	117 (42.5)*	674 (29.5)	150 (36.0)*
Moderately active	212 (15.5)	53 (19.3)	339 (14.8)	64 (15.3)
Vigorously active	624 (45.7)	105 (38.2)	1272 (55.7)	203 (48.7)
Current smoking, n (%)	914 (67)	188 (68)	89 (3.9)	16 (3.8)
Current drinking, n (%)	524 (38)	126 (46)*	17 (0.7)	3 (0.7)
Red meats, n (%)	1101 (80.6)	222 (80.7)	1637 (72.8)	310 (76.2)
Seafood, n (%)	1155 (84.6%)	232 (84.4)	1704 (75.8)	309 (75.9)
Soy product, n (%)	860 (63.0)	178 (64.7)	806 (35.9)	135 (33.2)
Milk, n (%)	579 (42.4)	110 (40.0)	618 (27.5)	99 (24.3)
Juice, n (%)	175 (12.8)	44 (16)	138 (6.1)	23 (5.7)
Nutrients, n (%)	106 (7.8)	23 (8.4)	57 (2.5)	9 (2.2)
Tea drink (mg/week)	56.7 (44.5, 68.9)	47.5 (40.7, 54.2)	20.3 (17.0, 23.7)	67.3 (55.2, 87.7)**
Fruit and vegetables intake (g/d)	337 (321, 353)	301 (269, 333)	306 (294, 317)	270 (230, 309)
Total fruit intake (g/d)	65.5 (60.5, 70.5)	58.2 (46.4, 70.0)	81.9 (77.5, 86.2)	61.6 (49.8, 73.4)*
Total vegetable intake (g/d)	272 (258, 285)	243 (216, 269)	224 (214, 233)	208 (171,245)

Data are mean (95% confidence interval) or number (percentage).
* $p<0.05$, ** $p<0.01$, *** $p<0.001$ for the difference between diabetic and non-diabetic participants

but the trend did not change substantially. Total vegetable intake was not associated with diabetes in men or women.

As shown in table 3, the effects of seafood, red meat, and soy and dairy products on diabetes prevalence were also assessed. Seafood intake was significantly associated with a lower risk of type 2 diabetes in a multivariable model. The corresponding ORs were 0.58 (0.35, 0.96) for men and 0.92 (0.63, 1.36) for women. Calcium, iron, and vitamin supplements did not significantly affect type 2 diabetes prevalence in a multivariable adjusted model, with corresponding ORs (95% CIs) of 0.99 (0.83, 1.18), 0.95 (0.63, 1.43), and 1.08 (0.98, 1.21) for men and 0.97 (0.83, 1.14), 0.91 (0.60, 1.38), and 1.14 (0.88, 1.47) for women. Yogurt intake was associated with a reduction in the risk of diabetes in women, but not in men, with an OR (95% CI) of 0.56 (0.32, 0.98) and 0.98 (0.69, 1.38), respectively.

DISCUSSION

Our study showed that women who consumed more fruit, vegetables, and yogurt had a lower prevalence of type 2 diabetes, but this association was not observed in men. After we adjusted for conventional factors, the inverse association was attenuated but still significant in women.

According to our findings, an inverse association between vegetable and/or fruit intake and type 2 diabetes has been indicated in both cross-sectional and prospective studies.[16,17] However, other studies have shown no relationship between fruit and/or vegetable intake and type 2 diabetes risk or levels of hemoglobin A1c.[18-20] Recently, a meta-analysis that included prospective studies from the United States, Europe, and China showed a weak inverse association between incident diabetes and total intake of fruit and leafy green vegetables, but not all types of vegetables.[21] One study suggested that a diet characterized by high intake of vegetables and intake of a variety of fruit and vegetables was associated with a reduced risk of diabetes.[22] Several clinical trials have also indicated that a diet rich in vegetables and fruit could prevent the development of diabetes in high-risk individuals.[23,24] Although our results and previous observational studies indicated that high intakes of fruit and vegetables were beneficial, the association may be mediated by other healthy personal behaviors.

Remarkably, three prospective longitudinal cohort studies have indicated that greater consumption of specific whole fruits were significantly associated with a lower risk of type 2 diabetes, whereas greater fruit juice consumption was associated with a higher risk.[25] Similarly, higher soft drink intake was associated with an increased risk of type 2diabetes in Japanese women, but not in Japanese men.[26] By contrast, fresh fruit and juice were combined in our multivariable model, adjusting for other conventional factors, indicating that only fresh fruit was sig-

Table 2. Odds ratios (95% CIs) of the presence of diabetes according to intake of total fruit and vegetables, total fruit and total vegetables

	Men						Women					
	Group 1	Group 2	Group 3	Group 4	OR for trend	*p* for trend	Group 1	Group 2	Group 3	Group 4	OR for trend	*p* for trend
Total fruit and vegetables intake (g/d)	<100	≥100-300	300-427	≥427			<100	100-300	300-427	≥427		
N	359	364	454	464			644	706	732	620		
Model 1	1.00	1.06 (0.72, 1.56)	1.00 (0.69, 1.46)	0.73 (0.49, 1.08)			1.00	0.79 (0.59, 1.06)	0.71 (0.53, 0.96)	0.68 (0.49, 0.94)		
Model 2	1.00	1.03 (0.70, 1.54)	1.03 (0.70, 1.51)	0.71 (0.47, 1.06)			1.00	0.70 (0.52, 0.95)	0.66 (0.49, 0.90)	0.64 (0.46, 0.89)		
Model 3	1.00	1.04 (0.68, 1.59)	1.02 (0.66, 1.56)	0.73 (0.46, 1.16)	0.93 (0.79, 1.04)	0.23	1.00	0.73 (0.53, 1.01)	0.68 (0.48, 0.97)	0.65 (0.44, 0.95)	0.87 (0.77, 0.98)	0.04
Total fruit intake (g/d)	<1.0		1.0-100	≥100			0		1.0-100	≥100		
N	458		700	483			689		1015	998		
Model 1	1.00		0.87 (0.64, 1.19)	0.68 (0.48, 0.98)			1.00		0.75 (0.58, 0.97)	0.51 (0.38, 0.68)		
Model 2	1.00		0.91 (0.66, 1.25)	0.67 (0.47, 0.97)			1.00		0.71 (0.54, 0.93)	0.48 (0.36, 0.64)		
Model 3	1.00		0.90 (0.64, 1.26)	0.66 (0.45, 0.97)	0.84 (0.70, 1.01)	0.06	1.00		0.77 (0.58, 1.03)	0.52 (0.38, 0.71)	0.71 (0.61, 0.82)	<0.0001
Total vegetables intake (g/d)	<42.7		42.7-<300	≥300			<42.7		42.7-<300	≥300		
N	382		443	816			752		887	1063		
Model 1	1.00		1.00 (0.69, 1.46)	0.94 (0.67, 1.32)			1.00		0.89 (0.68, 1.17)	0.86 (0.65, 1.12)		
Model 2	1.00		0.60 (0.66, 1.41)	0.94 (0.67, 1.33)			1.00		0.82 (0.62, 1.08)	0.81 (0.62, 1.07)		
Model 3	1.00		1.02 (0.68, 1.54)	1.00 (0.67, 1.50)	1.02 (0.85, 1.24)	0.82	1.00		0.89 (0.66, 1.21)	0.88 (0.63, 1.22)	0.96 (0.81, 1.12)	0.57

Model 1: adjusted for age, family history of diabetes. Model 2: Model 1 plus body mass index, systolic blood pressure. Model 3: Model 2 plus physical activity, 24-h energy intake, education level, smoking status ,drinking status, meats, seafood, drinks, dairy products, soy products, nutrients supplement and tea drink.

Table 3. Odds ratios (95% CIs) of the presence of diabetes according to intake of total fruit and vegetables, total fruit and total vegetables

	Men	Women
Age	1.04 (1.03, 1.06)	1.06 (1.05, 1.08)
BMI	1.09 (1.04, 1.14)	1.07 (1.04, 1.11)
Systolic blood pressure	1.02 (1.01, 1.03)	1.02 (1.01, 1.02)
Education	0.83 (0.61, 1.13)	0.85 (0.67, 1.09)
Family history of diabetes	3.48 (2.34, 5.23)	2.55 (1.85, 3.54)
Family income	1.36 (1.02, 1.80)	0.97 (0.76, 1.24)
Physically activity level	0.96 (0.82, 1.13)	0.98 (0.85, 1.12)
Current smoking	1.26 (0.91, 1.74)	1.01 (0.55, 1.85)
Current drinking	1.24 (0.91, 1.69)	0.95 (0.24, 3.82)
Red meats	0.93 (0.78, 1.12)	0.98 (0.85, 1.12)
Seafood	0.58 (0.35, 0.96)	0.92 (0.63, 1.36)
Soy product	0.96 (0.85, 1.09)	1.05 (0.94, 1.18)
Milk	0.99 (0.83, 1.19)	0.96 (0.86, 1.08)
Yoghurt	0.98 (0.69, 1.38)	0.56 (0.32, 0.98)
Juice	1.00 (0.79, 1.26)	0.93 (0.77, 1.13)
Nutrients	1.02 (0.96, 1.09)	1.12 (0.85, 1.18)
Tea drink	1.05 (0.88, 1.26)	0.98 (0.89, 1.08)
Total fruit and vegetables intake (g/d)		
<100	1	1
≥100-<300	1.09 (0.70, 1.70)	0.73 (0.53, 1.02)
300-<427	1.08 (0.69, 1.68)	0.70 (0.49, 1.00)
≥427	0.80 (0.49, 1.30)	0.67 (0.45, 0.99)

Model 1: adjusted for age, family history of diabetes. Model 2: Model 1 plus body mass index, systolic blood pressure. Model 3: Model 2 plus physical activity, 24-h energy intake, education level, smoking, drinking status, meats, seafood, soft drinks, dairy products, soy products, nutrients and tea drink.

nificantly related to a reduction in the risk of diabetes, whereas juice was related to a moderate increase in the risk of diabetes. The current conclusions require further investigation in a longitudinal data analysis.

The explanation for the differences between men and women regarding the association between fruit and vegetable intake and risk of diabetes is unclear. However, the result from a prospective study in US adults was in line with our study, showing that fruit and vegetable intake was inversely related to incident diabetes in women, but not in men.[27] However, in a Japanese prospective study, a modest reduction in type 2 diabetes risk was associated with intakes of green leafy vegetables in both men and in women, as well as total vegetable intake in men.[28] Food frequency questionnaires are less suitable for the assessment of absolute intake because they tend to overestimate or underestimate when analyzing types and varieties of foods. Higher recall bias might have been generated because compared with Chinese women; Chinese men generally cook less frequently and have a greater variety of social activities. In addition, gender differences regarding cigarette smoking, alcohol consumption, and obesity affected the primary results, even accounting for the aforementioned confounding factors considered in the adjustment of the final model. Estrogen and menopause replacement therapy might also influence fruit and vegetable absorption and utilization in women. The mechanisms of these gender differences require further investigation.

Total dairy intake has been reported to be associated with a decreased risk of type 2 diabetes in several meta-analyses.[29-31] Intake of high-fat dairy products was inversely associated with incident type 2 diabetes, whereas high intake of low-fat dairy products was associated with an increased risk in Malmö Diet and Cancer cohorts.[32] Consistent with our findings, greater low-fat fermented dairy product intake, largely consisting of yogurt, was associated with a decreased risk of type 2 diabetes in prospective analyses from the EPIC-Norfolk Study.[33] Although calcium, vitamin D, and magnesium in dairy products may affect insulin secretion and insulin sensitivity, further adjusting for conventional factors did not alter the trends in our findings. Menaquinones, which are found in probiotic bacteria in fermented dairy products, have been shown to improve lipid profiles and antioxidant status in individuals with type 2 diabetes. These findings suggest that the consumption of specific dairy types may aid in diabetes prevention. Because of the lack of classifications for high- and low-fat dairy products and low consumption of cheese in the typical Chinese diet, the association between dairy product consumption and diabetes risk requires further investigation.

Although several biological mechanisms have been proposed to explain an inverse association between fruit and vegetable intake and diabetes, the mechanism is not clear. Higher plasma vitamin C levels and, to a lesser degree, fruit and vegetable intakes are associated with a substantially decreased risk of diabetes.[34-36] Fruit and vegetables are rich in fiber, which has been indicated to improve insulin sensitivity and thus aid in overcoming insulin resistance. One recent study indicated that inverse associations were observed between vegetable, cereal, and total fiber intake and the risk of type 2 diabetes in 8 European countries.[37] Further mechanistic studies are required to explore the association between fruit and vegetable intake and type 2 diabetes.

The current paper is valuable because it describes a larger, population-based study, which identified type 2 diabetes by using a standard OGTT. However, our study also had several limitations. This study employed a cross-sectional design; therefore we could not evaluate the

causal relationship between fruit and vegetable intake and the risk of diabetes. Because of the lack of information on the specific types of vegetables and fruit, we could not examine whether different types of vegetables or fruit influence diabetes prevention.

Our study indicated a moderate association between greater fruit, vegetable, seafood, and dairy intake and a lower prevalence of type 2 diabetes. These results require confirmation, preferably from prospective or intervention studies.

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AUTHOR DISCLOSURES

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