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VEGETABLE BUT NOT FRUIT CONSUMPTION REDUCES THE RISK OF TYPE 2 DIABETES IN CHINESE WOMEN[1]

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Abstract

We examined associations between fruit and vegetable intake and the incidence of type 2 diabetes (T2D5) in a population-based prospective study of 64,191 women with no history of T2D or other chronic diseases at study recruitment and with valid dietary information. Dietary intake was assessed by in-person interviews using a validated food frequency questionnaire. During 297,755 person-years of follow-up, 1,608 new cases of T2D were documented. A Cox regression model was employed to evaluate the association of fruit and vegetable intake (g/d) with the risk of T2D. We observed an inverse association between quintiles of vegetable intake and T2D. The relative risk for T2D for the upper quintile relative to the lower quintile of vegetable intake was 0.72 (95%CI: 0.61-0.85, P<0.01) in multivariate analysis. Individual vegetable groups were all inversely and significantly associated with the risk of T2D. We did not find an association between fruit intake and the incidence of diabetes in this population. Our data suggest that vegetable consumption may protect against the development of T2D.

Keywords

type 2 diabetes; fruit and vegetable intake; middle-aged women

1. INTRODUCTION

Fruit and vegetable consumption may play a protective role in the development of type 2 diabetes (T2D), as they are rich in nutrients and other components that are believed to be protective against diabetes, such as antioxidants (1) and fiber (2). Fruits and vegetables also contain numerous other beneficial phytochemicals, many of which are not documented in nutrient databases.

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[5]Abbreviations used: BMI, body mass index; FFQ, food frequency questionnaire; HbA1c, Hemoglobin A1c; MET, metabolic equivalent; OGTT, oral glucose tolerance test; RR, risk ratio; SWHS, Shanghai Women's Health Study; T2D, type 2 diabetes; WHR, waist-to-hip ratio.

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Data on the associations between fruit and vegetable intake and the risk of T2D is limited and inconsistent (3), and some studies were not properly adjusted for potential confounders (4-6), which is a problem, as fruit and vegetable consumption may act as a 'marker' for a healthy lifestyle. To our knowledge, only three studies have evaluated associations between specific subgroups of vegetables with HbA1c and T2D incidence respectively (3;7;8).

Asian populations traditionally have a lower risk of T2D and obesity than Western populations. However, that appears to be changing. The prevalence of both obesity and T2D have been increasing in Asian populations in recent years (9). In the baseline survey of the Shanghai Women's Health Study (10) (conducted between 1997 and 2000), we found that the prevalence of T2D was 5.7% and the prevalence of obesity as measured by BMI was 59.05% (BMI≥23 kg/m^2) and 35.15% (BMI≥25 kg/m^2) (unpublished data). Change in dietary patterns is also taking place in China, including an increase in meat intake and a decrease in vegetable intake (11). Higher vegetable intake has been associated with less weight gain (12;13), a strong predictor for T2D, in Western populations. However, the association of vegetable intake with T2D risk in Chinese populations has not been well studied (14).

We evaluated the association of fruit and vegetable intake levels with the incidence of T2D in a large, population-based prospective study of middle-aged women conducted in Shanghai, China, where consumption of vegetables, especially leafy green vegetables, is high. We explored whether specific subgroups of vegetables differentially affect T2D risk, and we evaluated the potential interactions of fruit and vegetable intake with obesity and physical activity categories.

2. METHODS

Study population

The Shanghai Women's Health Study (SWHS) is a population-based prospective cohort study of middle-aged women (40-70 y old) conducted in seven urban communities in Shanghai, China. Details of the SWHS survey have been reported elsewhere (10). From a total of 81,170 women who were invited to participate, 75,221 were recruited (92.7% participation rate). Reason for non-participation were refusal (3.0%), absence during the enrollment period (2.6%), and other reasons such as health, hearing, speaking problems (1.6%). After exclusion of women younger than 40 y or older than 70 y at the time of interview, (N=278), 74,942 women remained for the study. Participants completed a detailed survey including an in-person interview for assessment of dietary intake, physical activity and measurement of anthropometrics and other lifestyle factors. Protocols for the SWHS were approved by the Institutional Review Boards of all institutes involved in the study, and all participants provided written, informed consent. Biannual in-person follow-up for all living cohort members was conducted via in-home visits conducted from 2000 to 2002 and from 2002 to 2004, with a response rate 99.8% and 98.7%, respectively; only 934 participants were lost to follow up. A total of 64,227 participants were free of T2D and other chronic diseases (cancer and cardiovascular disease) at baseline and they form the basis of this report.

Fruit and Vegetable Intake

Usual dietary intake was assessed through an in-person interview using a validated food frequency questionnaire (FFQ) at the baseline recruitment survey and again at the first follow-up survey (15). If women had a history of T2D, cancer, or cardiovascular disease reported between the baseline and follow-up surveys, we used dietary data from the baseline FFQ in the analysis. For other participants we used the mean of the baseline and follow-up FFQ data. The mean of the daily intake of individual food items (g/d) was combined to compute total fruit and vegetable intake. Soy beans, dried beans, and other legumes were not included as vegetables and were evaluated in a separate report. We created specific vegetable groups including cruciferous, green leafy vegetables, yellow vegetables, tomatoes, allium vegetables, and other vegetables (see appendix). The Chinese Food Composition Tables (16) were used to estimate energy intake (kJ/d) and nutrient intake. Of 64,227 participants who were free of T2D and other chronic diseases at baseline, we excluded participants who had extreme values for total energy intake (<2,090 or > 14,630 kJ/d; n=36) (17), which left 64,191 participants for the final analysis.

Other factors as potential confounders

All anthropometric measurements including weight, height, and circumferences of waist and hips were taken at baseline recruitment according to a standard protocol by trained interviewers who were retired medical professionals (18). From these measurements, the following variables were created: body mass index (BMI): weight in kg divided by the square of height in meters, waist-to-hip ratio (WHR): waist circumference divided by hip circumference.

A detailed assessment of physical activity was conducted using a validated questionnaire (19). The questionnaire evaluated regular exercise and sports participation during the last 5 years, daily activity, and the daily commuting round-trip journey to work. We calculated the metabolic equivalents for each activity using a compendium of physical activity values (20). One metabolic equivalent (MET)-h/d is roughly equivalent to 4.18 kJ/kg/d or about 15 min of participation in moderate intensity (4 MET) activity for an average adult (20). We combined each of the exercise and lifestyle activity indices to derive a quantitative estimate of overall non-occupational activity (MET-h/d). Occupation-related physical activity was not related to T2D in this population and thus, was not included in the current analysis.

Information on socio-demographic factors such as age, level of education (none, elementary school, middle/high school, college), family income in yuan/year (<10,000, 10,000-19,999, 20,000-29,999, ≥30,000), occupation (professional, clerical, farmers/others, housewife/ retired), smoking (smoked at least one cigarette per day for more than 6 months continuously) and alcohol consumption (ever drank beer, wine, or spirits at least 3 times per week), and presence of hypertension at baseline was collected by using a structured questionnaire.

Outcome Ascertainment

Incident T2D was identified through the follow-up surveys by asking study participants whether they had been diagnosed by a physician as having diabetes since the baseline recruitment and asking about their glucose test history and/or use of hypoglycaemic medication. A total of 1,608 study participants reported having a T2D diagnosis since the baseline survey. We considered a case of T2D to be confirmed if a participant reported having been diagnosed with T2D and met at least one of the following criteria as recommended by the American Diabetes Association (21): fasting glucose level greater than or equal to 7 mmol/l on at least two separate occasions, or an oral glucose tolerance test (OGTT) with a value greater than or equal to 11.1 mmol/L, and/or use of hypoglycaemic medication (i.e., insulin or oral hypoglycaemic drugs). Of the 1,608 self-reported cases, a total of 896 participants met the study outcome criteria and are referred to herein as confirmed cases of T2D. We performed analyses with both confirmed and probable T2D cases and found similar results.

Statistical analysis

Person-years of follow-up for each participant were calculated as the interval between the baseline recruitment to the diagnosis of T2D, censored at death or completion of the second follow-up survey. The Cox proportional hazards model was used to assess the association of fruit and vegetable intake with the incidence of T2D. Food groups (g/d) were categorized by quintile distribution with the lowest quintile serving as the reference. Tests for trend were performed by entering the categorical variables as continuous parameters in the models. Socio-demographic factors and T2D risk factors were adjusted for in the analyses as potential confounders. In all models we adjusted for the following potential confounding variables: age, BMI, WHR, total energy, meat intake, (all entered as continuous variables), as well as income level, education level, occupation, physical activity, smoking status, alcohol consumption status, and presence of hypertension at baseline (as categorical variables).

We conducted analyses stratified by BMI, WHR, and physical activity categories. The log-likelihood ratio test was used to evaluate multiplicative interactions between fruit and vegetable intake and categories of BMI, WHR, and physical activity.

We also conducted analyses adjusting for antioxidants (vitamin C, carotene, vitamin E) and fiber. To reduce measurement error and to adjust for extraneous variation due to total energy intake, we adjusted these nutrients by total energy intake by using the residual method described by Willett and Stampfer (22).

All analyses were performed using SAS (version 9.1), and all tests of statistical significance were based on two-sided probability.

3. RESULTS

The median intake for fruits and vegetables were 239.4 and 236.0 g/d, respectively. Age-standardized characteristics of the study population by fruit and vegetable intake are shown in Table 1. A higher intake of fruit was associated with younger age, higher physical activity, higher educational achievement, being employed, and higher household income. Participants with a higher fruit intake were more likely to have high BMI and less likely to be smokers. A higher vegetable intake was associated with younger age, high physical activity, higher BMI, higher WHR, presence of hypertension, and non-smoking status. Of participants in the highest quintile of vegetable intake who were free of chronic disease at baseline, the percentage with a BMI≥23 kg/m^2 was 56.7%, a BMI≥25 kg/m^2 was 32.64%, and BMI≥27.5 kg/m^2 was 13.10% (data not shown in tables).

During 4.6 years of follow-up (297,755 person-years total), 1,608 incident cases of T2D were documented. Vegetable intake was associated with a decreased risk of T2D. As compared with the lowest quintile of intake, the multivariate adjusted relative risk (RR) of T2D across quintiles of vegetable intake were 1.00, 0.74, 0.68, 0.72 and 0.72 (p for trend <0.001) (Table 2). Since participants with hypertension might have increased their fruit and vegetable intake following their diagnoses, we conducted analyses stratified by hypertension status (yes/no) and found similar results. The RR for quintiles of total vegetable intake were 1.00, 0.81, 0.65, 0.72 and 0.75 (P<0.001) and 1.00, 0.70, 0.71, 0.72 and 0.70 (P<0.001) for hypertensive and non-hypertensive participants, respectively (data not shown in tables). We also examined the association between deciles of vegetable intake and the incidence of T2D. The RR for deciles of vegetable intake were 1.00, 0.87, 0.68, 0.72, 0.61, 0.66, 0.67, 0.68, 0.64 and 0.71 (P<0.001) (data not shown in tables).

An inverse association was seen across quintiles of intake of cruciferous vegetables, green leafy vegetables, yellow vegetables, allium vegetables, tomatoes, and other vegetables. Although trend tests were highly significant, some of these inverse associations did not appear to follow a linear dose-response relationship. We did not find an association between fruit intake and the risk of T2D in this population. As compared with the lowest quintile of intake, the multivariate adjusted RRs of T2D across quintiles of fruit were 1.00, 0.76, 0.79, 0.87 and 1.05 (p for trend 0.30). Similarly, we did not find a significant association between individual fruit groups and the risk of T2D. The RRs associated with quintiles of consumption of citrus fruits, watermelon, and other fruits were 1.00, 0.84, 0.84, 0.81 and 1.11 (P=0.36), 1.00, 0.84,

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0.83, 0.90 and 1.04 (P=0.47) and 1.00, 0.77, 0.68, 0.85 and 0.90 (p=0.28), respectively (data not shown in tables).

In analyses restricted to confirmed diabetes cases, we found similar results (Table 3). We excluded participants who had been diagnosed with T2D during the first year of follow-up. The adjusted RR for T2D across quintiles relative to the lowest quintile were 1.00, 0.76, 0.68, 0.69 and 0.68 (P<0.001) for vegetables and 1.00, 0.81, 0.83, 0.88 and 1.08 (P = 0.31) for fruit (data not shown in tables).

We assessed potential effect modification by BMI (<25 or 25) and WHR (<0.85 and >0.85) and physical activity levels (using the lower 25% quartile as the cut off point of the MET distribution) with fruit and vegetable intake (Table 4). We did not observe that BMI, WHR or physical activity modified the association between fruit and vegetable intake and T2D.

We further explored whether the effect of fruit and vegetables in the development of T2D could be explained by antioxidants, fiber and magnesium (data not shown in tables). We added each nutrient in the model one at a time and in combination to examine whether the primary association with fruit or vegetable intake could be explained by nutrient intake. The inverse association between vegetable intake and T2D became slightly accentuated when the model included vitamin C, carotene, and fiber, or all antioxidants, magnesium and fiber together. The relative risk (RR) of T2D across quintiles of vegetable intake were 1.00, 0.71, 0.63, 0.63 and 0.56 (p for trend <0.001) in the analysis adjusted for fiber, magnesium, and all antioxidants. We observed a modest increase in risk of T2D in participants in the highest quintile of fruit intake after adjustment for vitamin C, carotene, fiber, and magnesium, and all antioxidants, magnesium, and fiber together. The RR for the highest quintile as compared to the lowest quintile for T2D in fully adjusted analysis was 1.21; (95%CI: 0.99-1.49). It is noteworthy that some of the nutrients were highly correlated with vegetable and fruit intake. Co- linearity may have limited our ability to sort out the factors responsible for the vegetable and diabetes association.

4. DISCUSSION

In this large, prospective, population-based study of middle-aged Chinese women, higher intake of vegetables was associated with a reduced risk of T2D. No association between fruit intake and T2D risk was found

Our study adds to the limited and conflicting data available on fruit and vegetable intake and the risk of T2D. An inverse association between vegetable but not fruit intake and glucose intolerance have been found in cross-sectional (6) and prospective studies (3;4;23), similar to our study. Inverse associations between both fruit and vegetable intake and the risk of glucose intolerance (5;8;24) and HbA1c (7) have been also been reported. However, other studies have found no association between fruit and/or vegetable intake and T2D risk (5;14;25-27) or levels of HBA1c (28). In a randomised control trial among 577 participants with impaired glucose tolerance conducted in China, a diet high in fruits and vegetables appeared to reduce the incidence of T2D by 24% (29). A diet high in fruit and vegetables was also associated with a higher insulin sensitivity in the Dietary Approaches to Stop Hypertension (DASH) intervention trial (30).

Few studies have looked at individual vegetable groups and the risk of T2D. Yellow and dark-green vegetable intake have been associated with lower HbA1c levels and T2D incidence (3; 7). In a middle-aged Finnish population, green vegetables but not yellow/red vegetables were associated with a lower incidence of T2D (8). In the Women's Health Study, BMI appeared to be an effect modifier on the association between green or dark-yellow vegetable intake and T2D (3). In our study, both green and yellow vegetable intake were inversely associated with

T2D. We found that neither BMI nor WHR modified the effect of vegetable intake on risk of T2D.

Several studies investigating the association between fruit and vegetable intake were based on cross-sectional surveys and adjusted for limited number of confounders. For example, in the Seven Countries study, an inverse relationship between vegetable intake and 2-hour glucose concentration in an OGTT was found, but the analyses were only adjusted for cohort, age, BMI, and energy intake (4). In a cross-sectional study of a Canadian native population a protective effect of vegetables on impaired glucose tolerance or T2D was reported (OR=0.41, 95%CI 0.18-0.91) (5). This analysis, however, was only adjusted for age and sex. Another cross-sectional study in the UK found a decreased risk of T2D associated with salad and raw vegetable consumption (OR=0.16, 95%CI, 0.04-0.81) with adjustment for age, sex, and family history of T2D (6). The association was attenuated when BMI was adjusted for. None of these studies adjusted for smoking habits, physical activity, or meat intake.

The mechanism by which vegetables affect glucose tolerance has not been clearly defined, but may be associated with the high content of antioxidants, (1) fiber (2), and magnesium (31) or the low glycemic index found in vegetables (32). Chronic administration of vitamin E has been reported to improve insulin sensitivity (33), and vitamin C was associated with higher insulin action in both healthy and diabetic people (34). However, in the Male Professionals study no association with the incidence of T2D was found after 12 years of supplementation with beta carotene (35). In our study, we found that the inverse association between vegetable intake and T2D persisted after adjustment for vitamin C, vitamin E, carotene, and fiber intake. Further adjustment for magnesium intake did not alter the association. Taking this evidence into consideration, it appears that the beneficial effects of vegetable consumption on the risk of T2D cannot be entirely explained by antioxidant vitamins, magnesium, or fiber intake. Vegetables also contain other compounds such as phytates, lignans, and isoflavones, which might have an additive or synergistic effect on lowering the risk of T2D.

Our data suggest that fruit consumption is not associated with a lower risk of T2D in this population. Other studies have found similar results (3;6;23;27). We do not have a ready explanation as to why fruit was not associated with a lower risk of T2D in our study population. We speculate that the high fructose content of fruit may counteract the protective effect of antioxidants, fiber, and other anti-diabetic compounds of fruit. It has been suggested that sugars containing fructose may play a major role in the development of hypertension, obesity, diabetes, the metabolic syndrome, and in the subsequent development of kidney disease (36). However, high serum uric acid concentrations, which have been associated with the metabolic syndrome (37), were not found to be related to fruit juice intake in a recent study using USA National Health and Nutrition Survey data (38). More research is needed to investigate the association between fructose in fruit and health outcomes.

Several alternative explanations should be considered when interpreting our findings. First, the exact benefit of fruit and vegetable intake is very difficult to assess when multiple factors such as exercise, not smoking, and maintaining a healthy weight may also be contributing a beneficial effect (the ‘healthy lifestyle bias’) and protecting participants from developing T2D. Fruit and vegetable consumption may act as a ‘marker’ for a healthy lifestyle and healthy dietary pattern in general (6;39). This is a potential problem in many observational studies of diet and disease, and it is difficult to exclude. However, in China dietary patterns are quite different from Western societies. Vegetables are widely consumed in Shanghai and less correlated with socio-economic status. Fruit intake, on the other hand, is associated with higher socio-economic factors in this population. Although we adjusted for education and income in the analysis, residual confounding remains a possible concern for our results, together with potential unmeasured confounders.

Participants in the SWHS are a representative sample of the Chinese, middle-aged female population in Shanghai. The prospective design, high participation rate, and high follow-up rates minimized the possibility of selection or recall bias. The repeated dietary measurements improved the quality of the dietary information and the extensive information available allowed us to adjust for a wide range of potentially confounding variables. An important limitation of our study is reliance on self-reports of T2D. Analyses restricted to participants whose diagnosis of T2D was confirmed according to our study criteria showed inverse associations between vegetable intake and the incidence of T2D. Recall of dietary intake is subject to misclassification. This kind of non-differential misclassification would tend to weaken associations between fruit and vegetable intake and T2D. The pre-diagnostic or pre-clinical manifestations of T2D might have lead to changes in diet. After we excluded probable cases of T2D and participants diagnosed within the first year of follow-up, our analyses showed a clearer linear association of vegetable intake with T2D than analyses which included the total population. Further follow-up of the cohort would provide a more definite assessment of the vegetable and T2D association.

Our study adds to the limited and conflicting data of the associations between fruit and vegetable intake and the risk of T2D. A higher intake of vegetables, rich in fiber, antioxidants, magnesium and with a low glycemic index, was associated with a decreased risk of T2D.

Appendix: Composition of food groups shown in Table 2

Food groups	Food items
Cruciferous vegetables	Green cabbage, Chinese cabbage, cauliflower, white turnip
Green leafy vegetables	Greens, Chinese greens, spinach
Yellow vegetables	Sweet potatoes, carrots
Allium vegetables	Garlic, garlic shoots, heads of garlic, onions, green onions, Chinese chives
Tomatoes	Tomatoes
Other vegetables	Soy bean sprouts, mug bean sprouts, black and white tree fungi, dried xiangu mushrooms, celery, eggplant, wild rice stems, asparagus lettuce, wax gourd, cucumbers, lufa, fresh mushrooms, peppers, bamboo shoots, lotus root
Fruits	Apples, pears, citrus (tangerines, oranges, grapefruit), banana, grapes, watermelon, peaches, other (strawberries, cantaloupe)

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Table I

Age standardized characteristics of participants of the Shanghai Women's Health Study stratified by fruit and vegetable intake

	FRUIT QUINTILES					VEGETABLE QUINTILES				
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Age y	53.9	51.7	50.6	49.9	48.8	53.0	51.1	50.5	50.3	50.0
Dietary factors										
KJ/day	6301.8	6650.8	6886.1	7100.6	7605.9	6069.8	6556.3	6891.6	7220.1	7832.5
Vitamin C mg/d	56.7	72.5	85.6	100.5	133.9	47.3	67.5	83.6	103.2	147.7
Vitamin E mg/d	10.4	12.2	13.4	14.6	17.1	9.5	11.7	13.2	15.0	18.3
Carotene ng/d	1921.4	2406.2	2812.4	3255.7	4166.7	1568.8	2232.5	2736.3	3340.5	4684.1
Fiber g/d	7.8	9.4	10.6	11.9	14.5	7.5	9.2	10.5	11.9	15.1
Meat Intake g/d[+]	55.5	62.1	65.4	67.8	73.0	52.5	60.4	64.8	69.9	76.2
WHR≥0.85 (%)	20.3	19.4	18.7	18.6	20.2	19.7	19.3	18.6	19.4	19.7
BMI (means) kg/m^2	23.4	23.6	23.8	23.9	24.2	23.6	23.6	23.8	23.8	24.1
BMI≥23 kg/m^2 (%)	54.6	54.7	56.5	57.5	61.4	52.2	54.7	56.3	58.1	62.3
BMI≥25 kg/m^2 (%)	32.0	30.4	32.1	32.1	36.5	29.9	30.7	32.5	33.2	36.8
BMI≥27.5 kg/m^2 (%)	13.7	12.5	12.6	12.6	14.8	11.7	12.1	13.0	13.3	15.5
Smoking (%)	3.9	2.0	1.6	1.2	1.7	2.9	2.3	1.8	1.8	2.0
Alcohol (%)	2.7	2.2	2.0	1.9	2.5	2.3	2.1	2.1	2.3	2.5
Exercise (%)	25.3	31.0	34.5	36.5	38.0	26.4	30.1	32.9	36.2	39.5
High PA[++] (%)	23.9	23.5	24.1	25.0	29.1	21.8	22.8	24.6	26.4	29.4
Education (%)										
None	21.7	19.1	17.8	16.5	15.6	24.6	18.5	15.9	15.0	14.9
Elementary	40.1	39.2	38.9	38.1	38.4	42.5	40.1	39.0	37.1	37.6
Up to high school	26.3	18.1	29.6	30.7	30.6	23.6	27.4	29.6	31.9	32.6
College	11.9	13.6	13.8	14.7	15.3	9.3	13.9	25.4	16.0	14.9
Income Level (%)										
<10000 yuan/y	21.6	15.4	13.7	13.1	13.3	15.7	15.1	14.9	14.8	16.6
10000-19999	41.8	40.0	37.8	36.7	34.8	37.8	38.1	37.9	38.7	37.7
20000-29999	24.3	28.4	30.3	30.0	29.6	29.4	28.9	28.9	28.5	27.3
≥30000	12.3	16.2	18.2	20.2	22.3	17.1	17.9	18.3	18.0	18.4
Occupation (%)										
Professional	14.9	19.4	21.4	22.0	21.0	19.1	20.4	20.1	20.6	19.3
Clerical	13.4	13.4	12.9	12.8	12.6	12.6	13.1	12.9	12.8	13.5
Manual workers/others	22.9	23.2	23.0	22.7	12.7	23.1	22.9	23.9	23.1	21.8
Housewife/retired	48.1	43.9	42.6	42.5	43.8	45.2	43.6	43.1	43.5	45.4
Hypertension (%)	18.5	18.2	19.4	18.7	19.4	16.8	18.5	19.1	19.6	20.2

[+] Meat intake is a composite variable that includes beef, poultry, pork and organ meat.

[++] High PA: upper quartile of the METs distribution of total non-occupational physical activity

Table 2

Hazard Ratio of type 2 diabetes by quintiles of food groups, the Shanghai Women's Health Study

	Q1	Q2	Q3	Q4	Q5	P trend*
All vegetables Median**	121.5	181.6	236.0	302.6	428.0	------
Cases	415	296	270	299	325	-------
person-years	59311	59858	59904	59524	9146	-------
HR	1.00	0.74 0.64-0.87	0.68 0.58-0.80	0.72 0.61-0.84	0.72 0.61-0.85	*<0.001*
Cruciferous vegetables Median	5.0	10.9	17.0	25.8	45.2	------
Cases	421	318	282	250	334	-------
person-years	59258	59744	59573	59738	59431	-------
HR	1.00	0.79 0.68-0.91	0.69 0.60-0.81	0.60 0.51-0.71	0.72 0.61-0.83	*<0.001*
Green/leafy vegetables Median	28.0	51.3	70.7	94.1	136.1	------
Cases	408	320	252	247	378	-------
person-years	59409	59820	59784	59867	58864	-------
HR	1.00	0.78 0.68-0.91	0.61 0.52-0.71	0.58 0.49-0.68	0.82 0.71-0.95	*<0.001*
Yellow vegetables Median	0.04	0.62	2.00	5.6	17.3	------
Cases	443	327	290	248	297	-------
person-years	58898	59419	59835	59552	59174	-------
HR	1.00	0.69 0.60-0.80	0.63 0.54-0.73	0.51 0.43-0.60	0.55 0.47-0.64	*<0.001*
Allium vegetables Median	2.2	4.2	6.5	9.8	17.9	------
Cases	393	309	286	293	324	-------
person-years	59540	59644	59835	59552	59174	-------
HR	1.00	0.79 0.68-0.92	0.70 0.60-0.81	0.70 0.60-0.82	0.69 0.59-0.81	*<0.001*
Tomatoes Median	6.8	17.0	30.3	49.2	88.5	------
Cases	469	285	298	244	309	-------
person-years	59080	59663	59648	59702	59651	-------
HR	1.00	0.68 0.59-0.79	0.73 0.63-0.85	0.61 0.52-0.71	0.78 0.67-0.91	*<0.001*
Other vegetables Median	40.7	66.8	90.9	121.4	181.0	------
Cases	398	285	317	286	319	-------
person-years	59106	60016	59656	59849	59117	-------
HR	1.00	0.76 0.65-0.88	0.84 0.72-0.98	0.76 0.64-0.89	0.76 0.64-0.89	*<0.01*
All fruits Median	87.0	170.4	239.4	315.0	4	------
Cases	421	271	270	288	355	-------
person-years	58846	59708	59733	59905	59555	-------
HR	1.00	0.76 0.65-0.88	0.79 0.67-0.92	0.87 0.74-1.02	1.05 0.90-1.23	*0.30*
Citrus fruit Median	2.5	10.0	16.7	25.2	44.4	------
Cases	402	292	278	262	371	------
Person-pears	58437	59594	60438	59389	59886	------
HR	1.00	0.84 0.72-0.98	0.84 0.72-0.98	0.81 0.69-0.95	1.11 0.95-1.29	*0.36*
Watermelon Median	29.6	71.3	109.7	149.1	221.0	------
Cases	390	295	280	294	346	------
Person-years	58907	59953	59815	59646	59424	------
HR	1.00	0.84 0.72-0.98	0.83 0.71-0.97	0.90 0.77-1.05	1.04 0.89-1.21	*0.47*
Other fruit Median	27.6	67.2	102.2	142.7	217.6	------
Cases	444	288	254	298	346	------
Person-years	58796	59636	59743	59721	59846	------
HR	1.00	0.77 0.66-0.90	0.68 0.58-0.80	0.85 0.73-0.99	0.90 0.77-1.05	*0.28*

* The Cox proportional hazards model was used to assess the effect of food group or soy protein consumption on the incidence of type 2 DM. RR: Adjusted for age, daily energy intake, meat intake, BMI, WHR, smoking, alcohol consumption, physical activity, income level, education level, occupational status, and hypertension

** g/day

*** Tests for trend were performed by entering the categorical variables as continuous parameters in the models.

Table 3

Hazard Ratio of type 2 diabetes by quintiles of food groups in analyses restricted to confirmed cases of diabetes*, the Shanghai Women's Health Study

	Q1	Q2		Q3		Q4		Q5		P_{trend}***
All vegetables**	1.00	0.71	0.58-0.87	0.66	0.54-0.81	0.69	0.56-0.85	0.65	0.52-0.81	*<0.001*
Cruciferous vegetables	1.00	0.83	0.68-1.01	0.75	0.61-0.92	0.69	0.56-0.85	0.70	0.56-0.86	*<0.01*
Green leafy vegetables	1.00	0.86	0.70-1.04	0.69	0.56-0.85	0.67	0.54-0.82	0.78	0.64-0.96	*<0.01*
Yellow vegetables	1.00	0.71	0.59-0.88	0.63	0.51-0.77	0.49	0.39-0.61	0.58	0.47-0.71	*<0.001*
Allium vegetables	1.00	0.89	0.73-1.09	0.65	0.52-0.81	0.85	0.69-1.04	0.84	0.68-1.03	*0.09*
Tomatoes	1.00	0.76	0.62-0.93	0.82	0.67-1.00	0.68	0.55-0.84	0.82	0.66-1.01	*0.02*
Other vegetables	1.00	0.74	0.60-0.90	0.75	0.61-0.93	0.75	0.60-0.85	0.68	0.54-0.85	*<0.01*
All fruits	1.00	0.71	0.58-0.88	0.73	0.59-0.90	0.86	0.70-1.05	0.94	0.76-1.16	*0.94*

* The Cox proportional hazards model was used to assess the effect of food group or soy protein consumption on the incidence of type 2 DM. RR: Adjusted for age, , daily energy intake, meat intake, BMI, WHR, smoking, alcohol consumption, physical activity, income level, education level, occupational status, and hypertension

** g/day

*** Tests for trend were performed by entering the categorical variables as continuous parameters in the models.

Table 4

Hazard Ratios of type 2 diabetes by fruit and vegetable intake stratified by BMI, WHR and physical activity[&], the Shanghai Women's Health Study

	Q1	Q2		Q3		Q4		Q5		P_{trend}[+]
All vegetables										
BMI<25[*]	1.00	0.59	0.45-0.76	0.64	0.49-0.83	0.69	0.53-0.90	0.68	0.51-0.90	*<0.001*
BMI≥25	1.00	0.85	0.71-1.02	0.71	0.59-0.87	0.77	0.63-0.94	0.79	0.64-0.96	*0.01*
P interaction 0.20										
WHR<0.85[**]	1.00	0.77	0.62-0.94	0.62	0.50-0.77	0.69	0.56-0.85	0.69	0.56-0.87	*<0.001*
WHR≥0.85	1.00	0.70	0.56-0.88	0.74	0.58-0.93	0.74	0.58-0.93	0.72	0.57-0.92	*<0.01*
P interaction 0.10										
Low PA[***]	1.00	0.74	0.56-0.99	0.56	0.40-0.76	0.75	0.56-1.00	0.60	0.43-0.84	*<0.01*
Medium/High PA	1.00	0.75	0.62-0.89	0.72	0.60-0.86	0.70	0.58-0.84	0.75	0.62-0.91	*<0.01*
P interaction 0.34										
Fruits										
BMI<25[*]	1.00	0.76	0.58-0.99	0.89	0.68-1.17	0.99	0.76-1.30	1.18	0.90-1.55	*0.08*
BMI≥25	1.00	0.72	0.60-0.87	0.72	0.59-0.87	0.79	0.65-0.96	0.98	0.81-1.18	*0.97*
P interaction 0.7										
WHR<0.85[**]	1.00	0.65	0.53-0.81	0.69	0.55-0.85	0.71	0.58-0.89	0.94	0.77-1.16	*0.80*
WHR≥0.85	1.00	0.85	0.67-1.06	0.89	0.70-1.12	1.06	0.84-1.33	1.12	0.89-1.42	*0.15*
P interaction 0.05										
Low PA[***]	1.00	0.63	0.47-0.86	0.81	0.60-1.09	0.84	0.62-1.13	0.79	0.57-1.08	*0.42*
Medium/High PA	1.00	0.80	0.67-0.96	0.77	0.64-0.93	0.87	0.73-1.05	1.14	0.95-1.36	*0.14*
P interaction 0.26										

[&] The Cox proportional hazards model was used to assess the effect of food group or soy protein consumption on the incidence of type 2 DM.

[+] Tests for trend were performed by entering the categorical variables as continuous parameters in the models.

[*] Adjusted for age, , daily energy intake, meat intake, WHR, smoking, alcohol consumption, physical activity, income level, education level, occupational status and hypertension

[**] Adjusted for age, , daily energy intake, meat intake, BMI, smoking, alcohol consumption, physical activity, income level, education level, occupational status and hypertension

[***] Adjusted for age, , daily energy intake, meat intake, BMI, WHR, smoking, alcohol consumption, income level, education level, occupational status, and hypertension