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Legume and soy food intake and the incidence of type 2 diabetes in the Shanghai Women's Health Study[1,2,3]

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Abstract

Background—It has been postulated that a diet high in legumes may be beneficial for the prevention of type 2 diabetes mellitus (type 2 DM). However, data linking type 2 DM risk and legume intake are limited.

Objective—The objective of the study was to examine the association between legume and soy food consumption and self-reported type 2 DM.

Design—The study was conducted in a population-based prospective cohort of middle-aged Chinese women. We followed 64 227 women with no history of type 2 DM, cancer, or cardiovascular disease at study recruitment for an average of 4.6 y. Participants completed in-person interviews that collected information on diabetes risk factors, including dietary intake and physical activity in adulthood. Anthropometric measurements were taken. Dietary intake was assessed with a validated food-frequency questionnaire at the baseline survey and at the first follow-up survey administered 2–3 y after study recruitment.

Results—We observed an inverse association between quintiles of total legume intake and 3 mutually exclusive legume groups (peanuts, soybeans, and other legumes) and type 2 DM incidence. The multivariate-adjusted relative risk of type 2 DM for the upper quintile compared with the lower quintile was 0.62 (95% CI: 0.51, 0.74) for total legumes and 0.53 (95% CI: 0.45, 0.62) for soybeans. The association between soy products (other than soy milk) and soy protein consumption (protein derived from soy beans and their products) with type 2 DM was not significant.

Conclusions—Consumption of legumes, soybeans in particular, was inversely associated with the risk type 2 DM.

Keywords

Type 2 diabetes; legume intake; soy intake; middle-aged women; Chinese women; protective factors

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INTRODUCTION

The prevalence of type 2 diabetes mellitus (type 2 DM) has been increasing rapidly worldwide (1); thus, knowledge of risk factors and protective factors associated with type 2 DM is essential for the development of prevention strategies.

Legumes—including beans, lentils, peanuts, peas, and soybeans—are good sources of fiber and have a low glycemic index. It has been postulated that a diet high in legumes may be beneficial for the prevention of type 2 DM. However, data linking type 2 DM risk and legumes are limited (2–4). One reason why the role of legumes in the prevention of diabetes is less documented could be due to the relatively low intake of leguminous foods in the populations studied (5). Soybeans alone may be associated with a lower risk of type 2 DM. In animal models of obesity and diabetes, soy protein has been shown to reduce serum insulin and insulin resistance (6). In studies of human subjects with and without type 2 DM, soy protein appears to moderate hypoglycemia, reduce body weight, and hyperinsulinemia (6). Peanuts may also be associated with a lower risk of type 2 DM because they contain fiber, magnesium, antioxidant vitamins, and polyunsaturated and monounsaturated fatty acids. Peanut consumption was associated with a lower incidence of diabetes in one study of US women (7), but not in another (8).

We examined the association between legumes and soy foods and the incidence of type 2 DM in a large population-based cohort study—the Shanghai Women’s Health Study (SWHS).

SUBJECTS AND METHODS

Study population

The SWHS is a population-based prospective cohort study conducted in 7 urban communities in Shanghai, China. All eligible women (n = 81 170) aged 40–70 y who resided in these communities were contacted. Participants were identified by using a roster obtained from resident offices in the study community. Trained interviewers visited potential study participants’ homes, explained the study, obtained written informed consent, and administered an interview between March 1997 and May 2000. A total of 75 221 women were enrolled, which yielded a participation rate of 92.7%. After the exclusion of 278 women who were later found to be younger than 40 y or older than 70 y at the time of the interview, 74 942 women remained for the SWHS. The major reasons for nonparticipation were refusal (3.0%), absence during the enrollment period (2.6%), and other miscellaneous reasons (ie, health, hearing, or speaking problems; 1.6%). All study participants completed a detailed survey, including an in-person interview for assessment of dietary intake, physical activity, and measurement of anthropometric and other lifestyle factors. Protocols for the SWHS were approved by the Institutional Review Boards of all institutes involved in the study. Details of the SWHS survey were reported elsewhere (9).

Dietary assessment

Dietary intake was assessed through an in-person interview with the use of a validated food-frequency questionnaire (FFQ) at the baseline recruitment survey, between 1997 and 2000, and at the first follow-up survey, between 2000 and 2002 (10). The SWHS FFQ includes 77 food items and food groups and covered 90% of the foods commonly consumed in urban Shanghai during the study period. For women who developed type 2 DM, cancer, or cardiovascular disease between the baseline and follow-up FFQs, we included only dietary data from the baseline FFQ in this analysis. For other participants the average of the baseline and follow-up FFQ data were analyzed. The average daily intake of individual food items (g/d) was combined to compute the following food groups: total legumes and 3 mutually exclusive groups [soybeans (dried and fresh), peanuts, and other legumes]. We also evaluated soy products such as soy milk, bean curd (tofu), fried bean curd, vegetarian chicken, and bean curd cake. Because soy milk is a beverage, we analyzed soy milk and "other soy products" separately.

The Chinese Food Composition Tables (11) were used to estimate intake of soy protein and energy intake (kcal/d). Soy protein refers to protein from all soy foods: soybeans, soy milk, and "other soy products." We further applied the residual method to adjust for variation due to total energy intake from soy protein (12).

Measurement of potential confounders

A structured questionnaire was used at the baseline survey to collect information on sociodemographic factors such as age, education level (none, elementary school, middle/high school, college), family income level (<10 000, 10 000–19 999, 20 000–29 999, >30 000 yuan/y), occupation (professional, clerical, manual laborers, housewife or retired), smoking (smoked ≥1 cigarette/d for >6 mo continuously), and alcohol consumption (ever drank beer, wine, or spirits ≥3 times/wk). Disease history, such as the diagnosis of diabetes, cancer, cardiovascular disease, or high blood pressure by a physician, was also collected.

All anthropometric measurements, including weight, height, and circumferences of the waist and hips, were taken at baseline recruitment according to a standard protocol by trained interviewers who were retired medical professionals (13). From these measurements, the following variables were created: body mass index (BMI; weight in kilograms divided by the square of height in meters) and waist-to-hip ratio (WHR; waist circumference divided by hip circumference).

A detailed assessment of physical activity was obtained with the use of a validated questionnaire (14). The questionnaire evaluated regular exercise and sports participation during the 5 y preceding the interview and provided information on daily activities such as walking, stair climbing, cycling, household activities, and daily commuting on the round-trip journey to work (walking and cycling). We calculated the metabolic equivalents for each activity using a compendium of physical activity values (15). One MET (metabolic equivalent)-h/d is roughly equivalent to 1 kcal $\cdot$ kg^{-1} $\cdot$ d^{-1} or ≈ 15 min of participation in moderate intensity (4 METS) activity for an average adult (15). We combined each of the exercise and lifestyle activity indexes to derive a quantitative estimate of overall nonoccupational activity (MET-h/d).

Cohort follow-up and endpoint ascertainment

In-person follow-up for all living cohort members was first conducted from 2000 to 2002 through an in-home visit. Follow-up for disease outcomes was completed for 74 755 cohort members, with a response rate of 99.8%. A second in-home follow-up survey was launched in May 2002 and completed in December 2004, with a response rate of 98.7%; only 934 participants were lost to follow-up.

Incident type 2 DM was identified through the follow-up surveys by asking study participants whether they had been diagnosed by a physician as having diabetes since baseline recruitment and asking about their glucose test history. A total of 1608 study participants reported a type 2 DM diagnosis since the baseline survey. For the current study we considered a case of type 2 DM to be confirmed if the participant reported having been diagnosed with type 2 DM and met at least one of the following criteria: *1*) fasting glucose concentration ≥7 mmol/L on 2 separate occasions, *2*) an oral-glucose-tolerance test with a value ≥11.1 mmol/L, and *3*) use of hypoglycemic medication (ie, insulin or oral hypoglycemic drugs). Of the self-reported cases, a total of 896 participants met the study outcome criteria and are referred to herein as confirmed cases of type 2 DM. We performed analyses restricted to confirmed cases and for all cases of type 2 DM and found similar trends. Thus, in this article we present results with all cases of type 2 DM included. Participants with cardiovascular disease, cancer, diabetes, or a positive urinary glucose test at the time of the baseline survey were excluded from the analyses. The total follow-up time was 4.6 y.

Statistical analysis

From 64 227 participants who were free of type 2 DM and other chronic diseases (cancer and cardiovascular disease) at baseline, we excluded participants who had extreme values for total energy intake (<500 or >3500 kcal/d; $n = 36$) (16), which left 64 191 participants for the analysis.

Person-years for each participant were calculated as the interval between baseline recruitment and diagnosis of type 2 DM, censored at death, or completion of the second follow-up survey. 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. Food groups (g/d) and soy protein (energy adjusted) 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 variables in the models. In all models we adjusted for the following potential confounding variables: age, BMI, WHR, total energy, energy-adjusted fiber intake, and vegetable 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). Because we previously reported that the association between soy and the prevalence of glycosuria may vary by menopausal status and BMI (17), we performed the analyses stratified by menopausal status and by categories of BMI and WHR. The log-likelihood ratio test was used to evaluate the interactive effects of food groups and soy protein intake with menopausal status, BMI categories, and WHR categories on type 2 DM risk. All analyses were performed by using SAS (version 9.1; SAS Institute Inc, Chicago, IL), and all tests of statistical significance were based on 2-sided probability.

RESULTS

The age-standardized characteristics of the participants by intake of legumes and total soy protein are shown in Table 1. A higher intake of total legumes was associated with higher exercise participation, higher educational level, and not having ever smoked. Participant characteristics with regard to intake of soybeans or other legumes were similar to those of total legumes. A higher total soy protein intake was associated with older age, higher exercise participation, higher alcohol consumption, and the presence of hypertension at baseline. The median intake for total legumes was 30.5 g/d, for soybeans was 11.0 g/d, for peanuts was 0.7 g/d, and for other legumes was 15.5 g/d (Table 2).

Associations between type 2 DM and quintiles of intake of legumes and total soy protein are presented in Table 3. Total legume consumption and consumption of soybeans, nuts, and other legumes were each associated with a decrease in risk of type 2 DM ($P < 0.001$). Soy milk consumption was also associated with a lower risk of type 2 DM. However, we found no significant association between consumption of other soy products or total soy protein and the risk of type 2 DM.

We further investigated associations between legumes and soy food consumption by menopausal status, BMI categories, and WHR categories (data not shown in tables). Consumption of legumes and consumption of soybeans were both inversely associated with the risk of type 2 DM among both premenopausal and postmenopausal women. The associations of legume and soybean consumption with risk of type 2 DM were not modified by BMI or WHR.

DISCUSSION

In this large, prospective, population-based study of middle-aged Chinese women, a higher intake of legumes, soybeans in particular, was associated with a reduced risk of type 2 DM.

Our study adds to the limited data on the associations between legume intake and the risk of type 2 DM. In the Dutch and Finnish cohorts of the Seven Countries Study (4), and in another study conducted in an elderly population, an inverse association between glucose concentration (after an oral-glucose-tolerance test) and frequent legume consumption was found (2), whereas no association between legume intake and type 2 DM incidence was found in the Iowa Women's Health Study of older women (3).

Legumes have been indirectly linked to a protective role in the development of type 2 DM as components of a prudent diet (18–20), which is associated with a lower risk of type 2 DM (20). Conversely, in another study, high consumption of legumes was linked to a dietary pattern associated with an increased risk of type 2 DM (21). However, the authors explained that, in that population legumes are typically consumed as part of a stew that also includes bacon, sausage, beef, or pork (21).

Our study is the first prospective, population-based study to look at usual soy food intake and incidence of type 2 DM. Soy intake is generally low in Western populations, which limits the ability of epidemiologic studies to determine associations between soy intake and type 2 DM. We previously reported an inverse association between soy protein from tofu and other soy products and the prevalence of glycosuria in postmenopausal women with a low BMI based on the baseline survey data of the SWHS (17). The ORs for quartiles of soy protein from tofu and other soy products in this group were 1.00, 1.00, 0.96, and 0.36 (P for trend = 0.004). In the current analysis, we found no interaction between menopausal status and total soy protein or soybean intake and the risk of type 2 DM. More studies are needed to fully understand the effect of soy intake on the development of type 2 DM and the underlying biological mechanisms.

The inverse association between peanut consumption and the risk of type 2 DM found in our study agrees with the Nurses' Health Study II, which found that consumption of both peanuts and peanut butter was protective against the development of type 2 DM (7). However, this result is not consistent with the Iowa study of older women, which suggested no association between peanuts and the incidence of type 2 DM (8).

The protective effect of legumes on type 2 DM may involve multiple biological pathways, including increased fiber content in the diet (22), a reduction in the glycemic index of mixed meals (23), or both. In addition, legumes contain polyphenols, such as isoflavones and lignans, which have an antioxidant effect and may be responsible for the protective role of legumes against the development of type 2 DM. Soy protein may reduce adiposity by inhibiting insulin secretion from pancreatic β cells or by inhibiting lipogenesis and enhancing lipolysis in the liver and adipocytes (6). Results from animal studies suggest that soy protein and soy isoflavone intake improve insulin sensitivity (24,25), and recent data suggest that isoflavones may exert antidiabetic effects in rats through peroxisome proliferators–activated receptors (26). Among postmenopausal women, dietary isoflavones and isoflavone supplementation have been associated with improved insulin resistance (27,28). However, epidemiologic evidence directly linking isoflavone intake with diabetes is limited (29). Peanuts may have a protective effect on type 2 DM because of their high content of polyunsaturated fatty acids, which have been shown to be associated with insulin sensitivity, and anti-oxidants, fiber, and magnesium, which

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have been shown to be associated with a lower risk of type 2 DM (7). Nut consumption has also been shown to be associated with a lower risk of coronary heart disease (30).

The wide range of soy foods and legumes consumed in our study facilitated the evaluation of the effect of usual soy food and legume consumption in this population. The population-based design and the high response and follow-up rates minimized the selection bias. The repeated dietary measurements improved the quality of the dietary information. In addition, we adjusted for a wide range of potential confounding factors in the analyses.

Nevertheless, our study has several limitations. Misclassification of dietary information, although unavoidable, would most likely be nondifferential and thus attenuate the true associations. Another limitation of our study is reliance on self-reports of type 2 DM. Under- and overreporting could lead to a biased estimation of the association between dietary factors and type 2 DM. When we repeated the analyses restricted to participants whose diagnosis of type 2 DM was considered to be confirmed according to our study criteria, we found similar results, although the CIs became wider because of the reduced sample size. Although we adjusted for several confounding variables, we cannot exclude the possibility of residual confounding.

In summary, we found that consumption of legumes was inversely associated with the risk of type 2 DM in this population. Our results add to evidence that shows a beneficial effect of the consumption of legumes in the development of type 2 DM.

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TABLE 1

Age-standardized characteristics of the study population by quintile (Q) intake of legumes (n = 64 191)

	Total legumes			Soybeans			Other legumes[2]		
	Q1	Q5	*P* for trend[1]	Q1	Q5	*P* for trend[1]	Q1	Q5	*P* for trend[1]
Age (y)	49 (44–63)[3]	49 (43–55)	<0.001	48 (43–50)	50 (44–60)	<0.001	51 (44–63)	47 (43–55)	<0.001
Energy intake (kcal/d)	1479.3 ± 321.7[4]	1848.9 ± 321.9	<0.001	1527.2 ± 335.8	1783.5 ± 333.5	<0.001	1498.5 ± 328.8	1827.6 ± 329.5	<0.001
BMI ≥ 25 kg/m^2 (%)	30.8 (30.0–31.6)	35.7 (34.9–36.5)	<0.001	31.2 (30.4–32.0)	35.1 (34.3–35.9)	<0.001	31.9 (31.1–32.7)	34.6 (33.8–35.4)	<0.001
Waist-to-hip ratio ≥ 0.85 (%)	20.1 (19.4–20.8)	19.1 (18.4–19.8)	<0.01	20.2 (19.5–20.9)	19.1 (18.4–19.8)	<0.01	19.8 (19.2–20.4)	19.7 (19.1–20.5)	0.24
Ever smoker (%)	2.7 (2.4–3.0)	2.2 (1.9–2.5)	<0.001	3.1 (2.8–3.4)	1.9 (1.6–2.2)	<0.001	3.2 (2.9–3.5)	1.8 (1.5–2.1)	<0.001
Alcohol consumption (%)	3.1 (2.8–3.3)	1.9 (1.6–2.2)	0.01	2.2 (1.9–2.5)	2.5 (2.2–2.8)	0.03	2.5 (2.2–2.8)	2.3 (2.0–2.6)	0.28
Exercise (%)	27.8 (27.0–28.6)	36.2 (35.4–37.0)	<0.001	28.9 (28.1–29.7)	35.5 (34.7–36.3)	<0.001	28.4 (27.7–29.3)	36.1 (35.3–36.9)	<0.001
Education (%)									
None	22.6 (21.9–23.4)	15.5 (14.9–16.1)	<0.001	22.1 (21.4–22.8)	15.6 (15.0–16.2)	<0.001	21.3 (21.7–21.9)	16.6 (16.0–17.2)	<0.001
Elementary	40.6 (39.8–41.4)	37.5 (36.7–38.3)		39.6 (38.8–40.4)	37.7 (36.9–38.5)		40.9 (40.1–41.7)	37.3 (36.5–38.1)	
Up to high school	25.3 (24.6–26.0)	32.0 (31.2–32.8)		25.6 (24.9–26.3)	32.4 (31.6–33.2)		26.3 (25.6–27.0)	30.5 (29.7–31.3)	
College	11.5 (11.0–12.0)	15.0 (14.4–15.6)		12.8 (12.2–13.4)	14.3 (13.7–14.9)		11.5 (11.0–12.0)	15.6 (15.0–16.2)	
Income level (%)									
<10 000 yuan/y	17.6 (17.0–18.2)	15.6 (15.0–16.2)	<0.001	17.2 (16.6–17.8)	15.4 (14.8–16.0)	<0.001	17.4 (16.8–18.0)	15.4 (14.8–16.0)	<0.001
10 000–19 999 yuan/y	37.8 (37.0–38.6)	38.7 (37.9–39.5)		37.2 (36.4–38.0)	38.1 (37.3–38.9)		38.2 (37.4–39.0)	38.2 (37.4–39.0)	
20 000–29 999 yuan/y	28.4 (27.6–29.2)	27.5 (26.8–28.2)		28.4 (27.6–29.2)	28.0 (27.3–28.7)		27.7 (26.9–27.5)	27.9 (27.2–28.6)	
>30 000 yuan/y	16.2 (15.6–16.8)	18.2 (17.5–18.9)		17.2 (16.6–17.8)	18.5 (17.9–19.1)		16.8 (16.2–17.4)	18.5 (17.9–19.1)	
Occupation (%)									
Professional	17.8 (17.1–18.5)	20.1 (19.4–20.8)	0.03	18.8 (18.1–19.5)	20.0 (19.4–20.6)	<0.001	17.7 (17.1–18.3)	20.6 (19.9–21.3)	0.29
Clerical	13.3 (12.7–13.9)	12.99 (12.3–13.5)		13.8 (13.2–14.4)	12.4 (11.9–12.9)		12.9 (12.3–13.5)	13.1 (12.5–13.7)	
Manual laborers	22.6 (21.9–23.3)	22.3 (22.6–23.0)		22.7 (22.0–23.4)	22.8 (22.6–23.4)		22.7 (22.0–23.4)	22.5 (21.8–23.2)	
Housewife or retired	46.2 (45.4–47.0)	44.7 (44.9–45.5)		44.7 (44.9–45.5)	44.8 (44.0–45.6)		46.7 (45.9–47.5)	43.7 (42.9–44.5)	
Hypertension (%)[5]	18.4 (17.7–19.1)	19.1 (18.4–19.8)	<0.001	18.5 (17.8–19.2)	19.4 (18.8–20.0)	<0.001	18.7 (18.1–19.3)	19.3 (18.6–20.0)	<0.001

[1] Calculated with a proportional odds model for the prevalences of population characteristics by ANOVA test for energy intake and with a Kruskal-Wallis test for age.

[2] Excludes peanuts and soybeans.

[3] Median; interquartile range in parentheses (all such values). Age was not normally distributed.

[4] $\bar{x}$ ± SD (all such values).

[5]Participants with a history of hypertension at baseline.

TABLE 2

Legume intake in the study population

	Legume intake		
	$\bar{x} \pm$ SD	Median	Interquartile range
		g/d	
Total legumes	35.9 ± 24.1	30.5	19.5–46.0
Soybeans	15.2 ± 15.4	11.0	5.6–19.3
Peanuts	1.5 ± 2.6	0.7	0.4–1.6
Other legumes	19.2 ± 14.8	15.5	9.4–24.7

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TABLE 3

Associations between the incidence of type 2 diabetes mellitus and consumption of legumes and soy food[1]

	Median	No. of events	Person-years	Relative risk	95% CI
All legumes (g/d)					
Quintile 1	12.3	412	59 111.2	1.00	
Quintile 2	21.7	300	59 763.3	0.73	0.63, 0.85
Quintile 3	30.5	303	59 835.2	0.72	0.62, 0.84
Quintile 4	42.1	277	59 889.1	0.61	0.52, 0.72
Quintile 4	65.0	313	59 145.6	0.62	0.51, 0.74
P for trend < 0.0001[2]					
Soybeans (g/d)					
Quintile 1	2.8	450	61 220.8	1.0	
Quintile 2	6.6	286	57 679.5	0.62	0.54, 0.73
Quintile 3	11.1	268	50 659.2	0.57	0.48, 0.60
Quintile 4	17.3	293	66 237.8	0.58	0.50, 0.68
Quintile 5	32.0	308	61 947.0	0.53	0.45, 0.62
P for trend < 0.0001[2]					
Peanuts (g/d)					
Quintile 1	0.1	377	61 220.8	1.00	
Quintile 2	0.4	269	57 679.5	0.80	0.69, 0.94
Quintile 3	0.7	289	50 659.2	0.95	0.82, 1.11
Quintile 4	1.4	333	66 237.8	0.79	0.68, 0.92
Quintile 5	3.1	337	61 947.0	0.80	0.68, 0.93
P for trend < 0.0001[2]					
Other legumes (g/d)[3]					
Quintile 1	5.6	433	60 706.7	1.00	
Quintile 2	10.7	291	57 566.9	0.78	0.67, 0.91
Quintile 3	15.5	291	59 808.2	0.78	0.67, 0.91
Quintile 4	22.3	294	60 216.8	0.78	0.67, 0.92
Quintile	37.1	296	59 445.7	0.76	0.64, 0.90
P for trend < 0.0001[2]					
Soy milk (g/d)					
None	0	592	82 534.8	1.00	
Low	12.3	191	54 592.4	0.52	0.39, 0.68
Medium	71.4	455	107 576.2	0.58	0.51, 0.66
High	214.3	367	53 040.9	0.61	0.54, 0.70
P for trend < 0.0001[2]					
Other soy products (g/d)					
Quintile 1	16.8	360	58 428.1	1.00	
Quintile 2	31.8	301	59 734.4	0.78	0.68, 0.93
Quintile 3	46.4	230	60 418.5	0.78	0.50, 0.70
Quintile 5	64.3	345	64 494.1	0.78	0.66, 0.90
Quintile 5	103.6	369	54 669.2	0.76	0.75, 1.04
P for trend = 0.13[2]					
Soy protein (g/d)					
Quintile 1	4.2	377	59 042.7	1.00	
Quintile 2	5.9	266	59 433.5	0.75	0.63, 0.88
Quintile 3	7.7	287	59 367.9	0.76	0.65, 0.89
Quintile 4	10.2	282	59 972.7	0.71	0.60, 0.84
Quintile 5	15.3	393	59 927.6	0.88	0.75, 1.04
P for trend = 0.13[2]					

[1] The Cox proportional hazards model was used to assess the effect of food group or soy protein consumption on the incidence of type 2 diabetes mellitus. The analyses were adjusted for age, energy intake, BMI, waist-to-hip ratio, smoking, alcohol consumption, vegetable intake, fiber, physical activity, income level, education level, occupation, and hypertension.

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

[3] Excluding peanuts and soybeans.