# Dietary Patterns and Incident Type 2 Diabetes in Chinese Men and Women

## The Singapore Chinese Health Study

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**OBJECTIVE**—To empirically derive dietary patterns and examine their association with incident type 2 diabetes.

**RESEARCH DESIGN AND METHODS**—We used data from the Singapore Chinese Health Study, including 43,176 Chinese men and women (aged 45–74 years), free of diabetes, cardiovascular disease, and cancer at baseline (1993–1998) and followed up through 2004. Two major dietary patterns were identified using principal components analysis: a vegetable, fruit, and soy-rich pattern (VFS) and a dim sum and meat-rich pattern (DSM). Pattern scores for each participant were calculated and examined with type 2 diabetes risk using Cox regression.

**RESULTS**—The associations of the two dietary patterns with diabetes risk were modified by smoking status. Neither pattern was associated with risk of diabetes in ever smokers. In never smokers, the VFS dietary pattern was inversely associated with risk of type 2 diabetes. Compared with the lowest quintile of the VFS dietary pattern score, the hazard ratios (HRs) for quintiles 2–5 were 0.91, 0.82, 0.73, and 0.75 ($P = 0.0005$ for trend). The DSM dietary pattern was positively associated with risk of type 2 diabetes in never smokers, with HRs for quintiles 2–5 of 1.07, 1.25, 1.18, and 1.47 ($P < 0.0001$ for trend).

**CONCLUSIONS**—A dietary pattern with higher intake of vegetables, fruits, and soy foods was inversely associated with risk of incident type 2 diabetes, and a pattern with higher intake of dim sum, meat and processed meat, sweetened foods and beverages, and fried foods was associated with a significantly increased risk of type 2 diabetes in Chinese men and women in Singapore.

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The prevalence of type 2 diabetes has increased threefold to fivefold in Southeast Asia during the past 3 decades across age and demographic groups (1). The prevalence of Chinese in Singapore nearly doubled from 1984 (4.7%) to 1998 (8.0%) (2). These increases in Southeast Asia are greater than those observed in the U.S. and other parts of the world (1,3). Substantive shifts in socioeconomic, demographic, and lifestyle patterns are thought to be responsible for this trend (1).

Dietary intake is central to these population trends and thus prevention and etiology of type 2 diabetes through its role in energy balance, insulin resistance, and glycemic control. Most research on diet and type 2 diabetes has focused on individual foods and nutrients. These data have proven valuable but are best interpreted in the scheme of an overall dietary pattern, which may be most germane to health (4).

Epidemiologic studies have examined associations between dietary patterns and the risk of type 2 diabetes (5–10). Generally, these studies suggest that higher intakes of vegetables and fruits, whole grains, fish, and low-fat dairy may be protective for diabetes risk, and higher intakes of processed grains, added sugars, processed and red meats, and fried foods may increase diabetes risk. In light of the similar dietary intakes and primarily Western dietary composition of the populations studied to date, more thorough research considering dietary patterns in a Chinese population may add further cultural and scientific insight into the diet and diabetes association.

The Singapore Chinese Health Study (SCHS) is a prospective cohort investigation of more than 63,000 Chinese men and women in Singapore. The aim of this study was to derive dietary patterns from this population and examine their association with risk of incident type 2 diabetes.

## RESEARCH DESIGN AND METHODS

### Study population

The design of the SCHS has been previously described (11). Briefly, the cohort was drawn from men and women, aged 45–74 years, who belonged to one of the major dialect groups (Hokkien or Cantonese) of Chinese in Singapore. Between April 1993 and December 1998, 63,257 individuals completed an in-person interview that included questions on usual diet, demographics, height and weight, use of tobacco, usual physical activity, menstrual and reproductive history (women only), medical history, and family history of cancer. A follow-up telephone interview took place between 1999 and 2004 for 52,325 cohort members (83% of recruited cohort). The institutional review boards at the National University of Singapore and the University of Minnesota approved this study.

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### Assessment of diet and covariates

A semiquantitative food frequency questionnaire that was specifically developed for this population assessing 165 commonly consumed foods was administered during the baseline interview to document the usual dietary intake of the previous year. During the interview, the respondent referred to accompanying photographs to select from eight food frequency categories (ranging from "never or hardly ever" to "two or more times a day") and three portion sizes. The food frequency questionnaire has been validated against a series of 24-h dietary recall interviews in a random sample of 1,220 participants (11) as well as in selected biomarker studies (12,13).

In conjunction with this cohort, the Singapore Food Composition Table was developed, a food-nutrient database that lists the levels of 96 nutritive/nonnutritive components per 100 g of cooked food and beverages in the diet of the Singaporean Chinese. By combining information obtained from the food frequency questionnaire with nutrient values provided in this food-nutrient database accounting for raw and cooked foods, we were able to compute the mean daily intakes of nutrients for each subject (11).

Other known or suspected risk factors for diabetes assessed with the baseline questionnaire included age (years), smoking habits/status (age started/quit, amount, frequency, type), highest educational level reached, BMI (kg/m$^2$) calculated using self-reported height and weight, and amount (hours) of moderate (e.g., brisk walking) and strenuous (e.g., jogging) physical activity each week.

### Assessment of diabetes

Self-reported diabetes as diagnosed by a physician was evaluated at baseline, and participants with a history of diagnosed diabetes were excluded from analysis. Diabetes status was assessed again by the following question asked during the follow-up telephone interview: "Have you been told by a doctor that you have diabetes (high blood sugar)?" If yes: "Please also tell me the age at which you were first diagnosed?" Participants were classified as having incident diabetes if they reported developing diabetes any time between the initial enrollment interview and the follow-up telephone interview that occurred between July 1999 and October 2004.

A validation study of the incident diabetes cases used two methods and was reported in detail in Odegaard et al. (14,15). On the basis of a hospital-based discharge summary database and a supplementary questionnaire regarding symptoms, diagnostic tests, and hypoglycemic therapy during a telephone interview, we observed a positive predictive value of 99% (14). Alternatively, 2,625 randomly selected participants who answered "no" to the question of diabetes diagnosis at baseline and follow-up, and provided blood samples at their follow-up interview, were analyzed for $HbA_{1c}$ (glycated hemoglobin). Of these, 148 (5.6% of the sample) had an $HbA_{1c}$ $\geq$6.5, meeting the most recent diagnostic guidelines for the presence of diabetes (16). Thus, 94.4% of persons who reported being free of diabetes at baseline and follow-up were below the $HbA_{1c}$ threshold for diabetes (15).

### Statistical analysis

Participants were excluded from the analysis if they died before the follow-up interview ($n$ = 7,722), reported baseline diabetes ($n$ = 5,469), cancer, heart disease, or stroke ($n$ = 5,975), reported extreme sex-specific energy intakes (<600 or >3,000 kcal women; <700 or >3,700 kcal men), or migrated out of Singapore ($n$ = 17). Also excluded were 20 participants whose diabetes status was not clear after the validation effort, which left 43,176 participants in the present analysis.

Dietary patterns were derived by principal component analysis (PCA) using SAS 9.1 software (SAS Institute Inc., Cary, NC). PCA in nutritional analyses aims to account for the maximal variance of dietary intake by combining the many different dietary variables into a smaller number of factors based on the intercorrelation of these variables. All 165 foods and beverages, including alcohol, were first standardized to the same frequency/month unit before the PCA method was applied and factors were extracted. The factors were rotated orthogonally to maintain an uncorrelated state and improve interpretability, and a two-factor solution was retained based on eigenvalues, scree plot, and factor interpretability. For comparability and interpretability of our results, we present factor loadings $\geq$0.20 even though values <0.20 are statistically significant due to the large sample size of the study. These parameters align with previous studies (5–9).

Factor scores for each participant were calculated by multiplying the intake of the standardized food item by their respective factor loadings on each pattern. The scores are linear variables and represent the weighted sum of all 165 food and beverage items. Participants were divided into quintiles by score to indicate the level at which their dietary intake corresponded with each pattern (i.e., a higher score corresponds with greater conformity to the derived pattern). Factors were initially extracted by sex, dialect, and smoking status and were highly similar in loading structure and disease prediction to the reported whole cohort factors, so the factors derived from the overall cohort were used.

Baseline and dietary characteristics were calculated for participants across quintiles of each dietary pattern score. Tests for trend across dietary pattern scores were performed by assigning the median value of the quintile to the respective categories and entering this as a continuous variable into the models. Person-years for each participant were calculated from the year of recruitment to the year of reported type 2 diabetes diagnosis, or year of follow-up telephone interview for those who did not report a diabetes diagnoses. Hazard ratios (HRs) per quintile of dietary pattern score were estimated by Cox proportional hazards regression models using the SAS statistical software. There was no evidence that proportional hazard assumptions were violated, as indicated by the lack of significant interaction between the dietary pattern scores and a function of survival time in the models.

Two models were constructed to examine the association between dietary pattern score and risk of type 2 diabetes. Covariates included in model I were baseline age (<50, 50–54, 55–59, 60–64, $\geq$65), year of interview (1993–1995 and 1996–1998), dialect (Hokkiens vs. Cantonese), sex, education (none, primary, secondary or higher), smoking (never, ever), any moderate or strenuous physical activity (yes vs. no), history of physician-diagnosed hypertension (yes vs. no), and total energy intake (kcal/day). Model II included these variables plus baseline BMI (kg/m$^2$ as the original BMI and its quadratic term [BMI$^2$]) because this may represent a mediator in this diet–diabetes relationship. Analyses testing for interactions of sex, age, smoking, physical activity, and BMI with the dietary pattern scores, as well as stratification, were completed. Lastly, sensitivity analyses excluding individuals with less than

2 years of follow-up were also done to account for confounding due to antecedent disease.

**RESULTS**—Of 43,176 men and women with 246,898 person-years of follow-up, 2,252 developed type 2 diabetes (5.2%). Individuals with incident diabetes were older, had a higher BMI, reported less physical activity and less education, and smoked more.

Two main dietary patterns were derived from PCA. The first pattern was named vegetable, fruit, and soy-rich (VFS), and factor loadings for this pattern ≥0.20 are summarized in Supplementary Table 1. The higher the loading (correlation) between a food and a factor the more that food uniquely contributes to the pattern score. Thus, foods loading highly on this pattern are predominantly vegetables, fruits, and soy-based items. The second pattern was named dim sum and meat-rich (DSM). Foods loading ≥0.20 on the DSM pattern are presented in Supplementary Table 2. A variety of foods, predominantly dim sum, fresh and processed meats and seafood, noodle and rice dishes, sweetened foods, and deep fried foods are prominent contributors to the pattern. Most dim sum foods are savory pastries, such as steamed or deep fried dumplings, filled buns, noodles, sweet pastries, and meat dishes.

Baseline characteristics and HRs are presented separately for ever smokers and never smokers because there was evidence that smoking modified the association between the dietary patterns and the incidence of type 2 diabetes. Overall, 31,326 participants reported no history of smoking and 1,570 developed type 2 diabetes (5.0%), and 11,850 reported a history of smoking and 682 developed type 2 diabetes (5.8%). Table 1 reports baseline characteristics of the study sample according to smoking status by quintile of the VFS dietary pattern score. Table 2 summarizes baseline characteristics by smoking status according to quintile of the DSM dietary pattern score.

HRs for incident type 2 diabetes by smoking status are presented in Table 3. Overall, there was no association between the DSM or the VFS dietary pattern score and type 2 diabetes in ever smokers. We evaluated potential effect modification through stratification by sex, BMI, age, physical activity, and smoking habits (current vs. former smokers, smoking intensity and duration), but the results did not differ.

Conversely, a statistically significant inverse association was observed for type 2 diabetes risk among never smokers with increasing conformity to the VFS pattern. Compared with the lowest quintile, there was a monotonic decrease in risk as the score increased in quintiles 2–4, and leveled off in the highest quintile (Table 3). The association persisted after adjustment for all potential confounders, including BMI. Tests for interaction between VFS pattern score in never smokers and BMI, physical activity, and age, as well as stratification efforts, provided no evidence of any effect modification with this pattern. Excluding individuals with less than 2 years of follow-up did not materially change the association.

For the DSM pattern in never smokers, the HR increased in the second through fifth quintiles of the DSM dietary pattern score compared with the first quintile of the DSM pattern score. A 47% increase in risk was observed in the fully adjusted model in the fifth quintile of the DSM score (HR 1.47; 95% CI 1.22–1.77, $P < 0.0001$ for trend) compared with the first quintile. This was nominally attenuated upon adjustment for BMI (Table 3). There was no evidence the association differed by sex, BMI, physical activity, or age. Excluding individuals with diabetes with less than 2 years of follow-up did not materially alter the results in any analysis considering the DSM dietary pattern score nor did consideration of case status from the validation study.

**CONCLUSIONS**—In this large prospective study of Chinese Singaporeans,

**Table 1—*Participant characteristics by smoking status across quintiles of vegetable, fruit, and soy-rich dietary pattern score: Singapore Chinese Health Study***

| | Ever smokers ($n$ = 11,850) | | | Never smokers ($n$ = 31,326) | | |
|---|---|---|---|---|---|---|
| Characteristic | Q1 | Q3 | Q5 | Q1 | Q3 | Q5 |
| Age (years) | 56.4 (7.7) | 57.0 (7.6) | 56.9 (7.8) | 55.0 (7.8) | 54.7 (7.5) | 54.2 (7.3) |
| BMI (kg/m$^2$) | 22.5 (3.1) | 22.8 (3.3) | 22.8 (3.2) | 23.3 (3.3) | 23.2 (3.1) | 23.0 (3.2) |
| Any physical activity (% ever) | 18.2 | 28.3 | 36.3 | 18.9 | 28.2 | 36.8 |
| Education (% secondary or greater) | 23.5 | 28.7 | 35.3 | 24.9 | 31.0 | 38.1 |
| Female (%) | 13.2 | 15.6 | 16.3 | 68.4 | 74.4 | 74.5 |
| Hypertension (%) | 14.1 | 18.9 | 19.0 | 20.0 | 20.9 | 20.3 |
| Dietary intakes | | | | | | |
| Total energy (kcal/day) | 1,526 (532) | 1,703 (517) | 2,098 (563) | 1,271 (446) | 1,443 (421) | 1,830 (494) |
| Carbohydrate (% energy) | 60.4 (8.1) | 59.2 (7.1) | 56.0 (7.2) | 61.6 (7.5) | 59.5 (6.6) | 56.4 (6.8) |
| Fat (% energy) | 22.3 (5.9) | 24.6 (5.3) | 27.9 (5.2) | 22.8 (5.7) | 25.1 (4.9) | 28.4 (4.9) |
| Saturated fat (% energy) | 8.4 (2.6) | 8.8 (2.4) | 9.6 (2.6) | 8.4 (2.6) | 8.8 (2.4) | 9.6 (2.5) |
| Monounsaturated fat (% energy) | 7.7 (2.2) | 8.3 (2.0) | 9.3 (2.0) | 7.8 (2.1) | 8.5 (1.9) | 9.4 (1.9) |
| Polyunsaturated (% energy) | 4.0 (1.3) | 4.8 (1.6) | 5.9 (2.0) | 4.3 (1.4) | 5.2 (1.7) | 6.2 (2.2) |
| Omega-3 fatty acids (g/day) | 0.7 (0.3) | 0.9 (0.4) | 1.3 (0.5) | 0.6 (0.3) | 0.8 (0.3) | 1.2 (0.5) |
| Omega-6 fatty acids (g/day) | 5.9 (2.9) | 8.0 (3.6) | 12.2 (5.3) | 5.4 (2.6) | 7.3 (3.1) | 11.4 (5.1) |
| Protein (% energy) | 14.1 (2.5) | 14.9 (2.3) | 15.6 (2.4) | 14.5 (2.4) | 15.3 (2.3) | 15.9 (2.4) |
| Soy protein (% total protein) | 6.8 (4.9) | 9.1 (5.3) | 12.6 (7.4) | 7.6 (5.4) | 9.6 (5.4) | 13.2 (7.4) |
| Fiber (g/1,000 kcal) | 5.7 (1.7) | 7.6 (2.0) | 9.3 (2.3) | 6.6 (1.9) | 8.5 (2.2) | 10.4 (2.6) |
| Starch (g/1,000 kcal) | 113.6 (26.0) | 107.0 (21.8) | 92.6 (20.3) | 116.0 (24.5) | 105.2 (20.7) | 89.6 (19.6) |

All values are mean (SD) except percentages (%).

**Table 2—*Participant characteristics by smoking status across quintiles of dim sum and meat-rich dietary pattern score: Singapore Chinese Health Study***

| | Ever smokers ($n$ = 11,850) | | | Never smokers ($n$ = 31,326) | | |
|---|---|---|---|---|---|---|
| Characteristic | Q1 | Q3 | Q5 | Q1 | Q3 | Q5 |
| Age (years) | 61.0 (7.2) | 57.2 (7.6) | 54.5 (7.3) | 56.9 (7.8) | 54.2 (7.2) | 52.3 (6.6) |
| BMI (kg/m$^2$) | 22.6 (3.2) | 22.7 (3.2) | 22.7 (3.2) | 23.1 (3.1) | 23.2 (3.2) | 23.2 (3.3) |
| Any physical activity (% ever) | 28.5 | 25.2 | 25.9 | 29.7 | 27.3 | 30.1 |
| Education (% secondary or greater) | 17.4 | 25.6 | 35.2 | 24.1 | 30.1 | 43.4 |
| Female (%) | 29.5 | 14.6 | 8.6 | 82.6 | 74.4 | 60.3 |
| Hypertension (%) | 20.1 | 17.6 | 14.6 | 22.6 | 19.8 | 18.3 |
| Dietary intakes | | | | | | |
| Total energy (kcal/day) | 1,313 (411) | 1,529 (411) | 2,176 (560) | 1,244 (368) | 1,474 (398) | 2,023 (518) |
| Carbohydrate (% energy) | 64.3 (6.9) | 60.5 (6.9) | 54.8 (6.7) | 62.8 (6.7) | 58.9 (6.5) | 54.4 (6.2) |
| Fat (% energy) | 21.2 (5.5) | 23.2 (5.3) | 27.6 (5.2) | 22.8 (5.2) | 25.5 (5.0) | 29.3 (4.7) |
| Saturated fat (% energy) | 7.3 (2.4) | 8.3 (2.3) | 10.3 (2.3) | 7.7 (2.4) | 8.9 (2.2) | 10.7 (2.2) |
| Monounsaturated fat (% energy) | 7.0 (2.0) | 7.9 (1.9) | 9.5 (1.9) | 7.5 (1.9) | 8.6 (1.8) | 10.0 (1.8) |
| Polyunsaturated (% energy) | 4.6 (2.0) | 4.6 (1.7) | 5.0 (1.5) | 5.1 (2.1) | 5.3 (1.9) | 5.6 (1.6) |
| Omega-3 fatty acids (g/day) | 0.7 (0.4) | 0.8 (0.3) | 1.2 (0.4) | 0.7 (0.3) | 0.9 (0.4) | 1.2 (0.5) |
| Omega-6 fatty acids (g/day) | 6.1 (3.8) | 6.9 (3.4) | 10.7 (4.5) | 6.4 (3.5) | 7.7 (3.8) | 11.2 (4.6) |
| Protein (% energy) | 14.0 (2.6) | 14.7 (2.4) | 15.3 (2.2) | 14.6 (2.5) | 15.4 (2.3) | 16.0 (2.1) |
| Soy protein (% total protein) | 10.1 (8.0) | 8.9 (6.3) | 8.8 (5.0) | 10.4 (7.6) | 9.9 (5.8) | 10.0 (5.3) |
| Fiber (g/1,000 kcal) | 8.6 (2.8) | 7.2 (2.2) | 6.8 (1.9) | 9.6 (3.0) | 8.4 (2.5) | 7.9 (2.0) |
| Starch (g/1,000 kcal) | 120.9 (24.0) | 110.9 (23.0) | 94.4 (20.0) | 113.0 (24.3) | 102.8 (21.5) | 89.9 (18.6) |

All values are mean (SD) except percentages (%).

two main dietary patterns were identified. A pattern characterized by high consumption of vegetables, fruit, and soy products was termed "VFS." The other dietary pattern was characterized by high consumption of dim sum, fresh and processed meats, higher levels of noodles and rice dishes, and some sweetened and deep fried foods and was termed "DSM." The associations with each pattern were modified by smoking status. Although smokers are at higher risk of developing type 2 diabetes, neither pattern was associated with diabetes risk among ever smokers. In never smokers, the VFS dietary pattern was inversely associated with type 2 diabetes risk, and the DSM dietary pattern was positively associated with type 2 diabetes risk.

The VFS pattern in the SCHS has similarities in loading structure and association with type 2 diabetes to dietary patterns termed "prudent" in the Nurses' Health Study (8), The Health Professionals Follow-up Study (9), and a Finnish study (7), all of which found suggestive or definitive inverse associations between this pattern and type 2 diabetes. These patterns were characterized by higher intake of vegetables, fruits, whole grains, legumes, fish, poultry, and low-fat dairy. There are also some similarities to cluster analysis-derived dietary patterns from the Shanghai Women's study, where a cluster with greater fruit and vegetables, dairy, meat, and seafood and less soy and rice was associated with a decreased risk compared with a cluster with greater rice, less meat and seafood, fruit, vegetable, dairy, and snack and dessert intake (10). This protective dietary cluster was also associated with significantly less obesity and hypertension as well as with younger age, higher education, and higher incomes. In the current study, the VFS pattern differs from previous Western populations examined in that a relatively high level of soy products are consumed in this population and essentially all the grains are refined or processed. Furthermore, dairy and nonsoy legumes are not prominent usual dietary components in this Chinese population. Regardless of the differences, the VFS pattern was associated with nutritional components such as higher fiber intake and fatty acids that may be beneficial for diabetes risk (17,18).

The DSM was the other main pattern in the SCHS. Similar to the previous studies on this topic that presented a dietary pattern with higher consumption of meats, fried foods, and sweetened foods and beverages, subjects in the current study who ate a diet highly conforming to the DSM pattern experienced a significantly increased risk of type 2 diabetes. These previous studies also noted higher levels of refined grains on their "Western" and "conservative" patterns (7–9).

Unlike previous studies on this topic, the associations in the current study were observed only in never smokers. Smoking has been shown to be a significant, independent causal risk factor for type 2 diabetes (19). Indeed, ever smokers in the SCHS have a higher incident rate of type 2 diabetes. Multiple pathways of pathophysiologic significance appear to be involved in the association of smoking and type 2 diabetes that could confound the association between dietary intake and type 2 diabetes, including smoking contributing to insulin resistance (20), oxidative stress, β-cell dysfunction (21,22), accumulation of greater abdominal fat compared with nonsmokers (20), and weight gain in those who quit, cycle, or smoke heavily (20). Other potential contributors to the association include the clustering of nonhealthy behaviors such as low levels of physical activity and poor diets, especially in individuals whose socioeconomic status is lower (19). Smoking also has significant effects on oral and intravenous glucose tolerance tests, thus influencing detection of diabetes (23). These potential causal and noncausal mechanisms may help explain why no inverse association was found in the VFS pattern in ever smokers.

Limited evidence is available on the topic of the interplay between diet and smoking on risk of diabetes. A study

**Table 3—*HRs of type 2 diabetes according to quintile of dietary pattern score by smoking status: Singapore Chinese Health Study***

| Variable | Q1 | Q2 | Q3 | Q4 | Q5 | *P* for trend |
|---|---|---|---|---|---|---|
| VFS pattern | | | | | | |
| Ever smokers | | | | | | |
| Incident cases/PY | 195/21,222 | 155/14,915 | 131/12,604 | 99/10,661 | 102/9,589 | |
| Incidence rate* | 92 | 104 | 104 | 93 | 106 | |
| Model I† | 1.0 | 1.13 (0.91–1.39) | 1.12 (0.89–1.40) | 1.01 (0.79–1.30) | 1.20 (0.92–1.55) | 0.30 |
| Model II‡ | 1.0 | 1.07 (0.87–1.33) | 1.07 (0.85–1.34) | 0.97 (0.76–1.25) | 1.17 (0.91–1.51) | 0.39 |
| Never smokers | | | | | | |
| Incident cases/PY | 304/29,136 | 334/35,322 | 319/36,782 | 298/38,079 | 315/38,588 | |
| Incidence rate* | 104 | 95 | 87 | 78 | 82 | |
| Model I† | 1.0 | 0.91 (0.78–1.06) | 0.82 (0.70–0.96) | 0.73 (0.62–0.86) | 0.75 (0.64–0.90) | 0.0005 |
| Model II‡ | 1.0 | 0.91 (0.78–1.06) | 0.82 (0.70–0.97) | 0.75 (0.64–0.89) | 0.77 (0.65–0.92) | 0.001 |
| DSM pattern | | | | | | |
| Ever smokers | | | | | | |
| Incident cases/PY | 74/7,823 | 127/11,649 | 144/13,848 | 160/16,142 | 177/19,529 | |
| Incidence rate* | 95 | 109 | 104 | 99 | 91 | |
| Model I† | 1.0 | 1.13 (0.85–1.51) | 1.07 (0.80–1.43) | 1.02 (0.77–1.37) | 0.93 (0.68–1.27) | 0.25 |
| Model II‡ | 1.0 | 1.11 (0.83–1.49) | 1.07 (0.80–1.42) | 1.03 (0.77–1.37) | 0.98 (0.72–1.35) | 0.55 |
| Never smokers | | | | | | |
| Incident cases/PY | 356/42,120 | 326/38,296 | 332/35,496 | 269/32,746 | 287/29,249 | |
| Incidence rate* | 84 | 85 | 94 | 82 | 98 | |
| Model I† | 1.0 | 1.07 (0.92–1.24) | 1.25 (1.07–1.46) | 1.18 (0.99–1.39) | 1.47 (1.22–1.77) | $<$0.0001 |
| Model II‡ | 1.0 | 1.05 (0.90–1.22) | 1.19 (1.02–1.39) | 1.13 (0.95–1.34) | 1.38 (1.14–1.66) | 0.001 |

Data for all models are presented as HR (95% CI). *Incidence rate is the incident of cases per 10,000 person-years (PY) of follow-up. †Adjusted for age, sex, dialect, year of interview, education, physical activity, hypertension, energy intake. ‡Adjusted for aforementioned variables and BMI (continuous and quadratic). VFS, vegetable, fruit, and soy-rich dietary pattern; DSM, dim sum and meat-rich dietary pattern.

examining oxidative stress and type 2 diabetes found that dietary factors did not explain the long-term effects of smoking on glucose homeostasis (24). In addition, a prospective study investigating serum carotenoid levels as a marker of a diet high in plant-based foods suggested that smoking annuls the potentially protective effect of high antioxidant consumption on diabetes risk, and antioxidant metabolism may be altered in smokers compared with nonsmokers (25).

On the other hand, hypothesizing a further increased risk in the DSM pattern in ever smokers would seem to be in line with current dietary and smoking evidence in relation to diabetes. Yet, our results provided no evidence to support this. Montonen et al. (7) conducted the only other study to investigate this interaction with overall dietary patterns and observed a greater increased risk in current smokers eating a poor diet compared with former or never smokers.

Strengths of the current study include the combination of prospective data and a non-Western population, which uniquely contributes to the literature. Another particular strength was the use of a food frequency questionnaire that was specifically developed and validated in this population. Others include the high participant response rate, detailed collection of data through face-to-face interviews, very low level of loss of participants to follow-up, and validated diabetic case status.

Limitations to consider in the interpretation of the study include the subjective nature of steps in PCA. However, we attempted to maintain objectivity in each of these steps and also used a standard method applied in previous studies. Inevitably, diet was measured with some error, although this would most likely result in nondifferential misclassification with respect to disease status and likely underestimation of risk. The self-report of other lifestyle related data may also result in some misclassification and residual confounding in our models.

Finally, these results may only apply to physician-diagnosed diabetes. Even with high levels of validity, there is potential for numerous individuals with undiagnosed type 2 diabetes due to the nature of the disease. If the dietary pattern led to increased or decreased physician diagnosis, the associations could be overestimated. Lastly, the dietary patterns identified by PCA represent usual intake of the study population as captured by a food frequency questionnaire but do not necessarily reflect the optimal or worst overall diet in relation to diabetes risk.

In conclusion, a dietary pattern characterized by higher intake of vegetables, fruits, and soy foods was inversely associated with risk of incident type 2 diabetes, and a pattern with higher intake of dim sum, meat and processed meat, sweetened foods and beverages, and fried foods was associated with a significantly increased risk of type 2 diabetes in a large cohort of Chinese men and women in Singapore. These associations were limited to never smokers, comprising 72.6% of the study population. Dietary patterns are unique to the populations they are derived from, yet consistencies across populations and cultures suggest that increased intake of plant-based foods, such as vegetables, fruits, soy and other legumes, whole grains, nuts, and seeds, likely decreases diabetes risk, while higher intake of processed meat, sweetened foods and beverages, fried foods, and refined grains increases risk of developing type 2 diabetes.

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