ORIGINAL RESEARCH

Plant-Based Diets Are Associated With a Lower Risk of Incident Cardiovascular Disease, Cardiovascular Disease Mortality, and All-Cause Mortality in a General Population of Middle-Aged Adults

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***Background*—**Previous studies have documented the cardiometabolic health benefits of plant-based diets; however, these studies were conducted in selected study populations that had narrow generalizability.

***Methods and Results*—**We used data from a community-based cohort of middle-aged adults (n=12 168) in the ARIC (Atherosclerosis Risk in Communities) study who were followed up from 1987 through 2016. Participants' diet was classified using 4 diet indexes. In the overall plant-based diet index and provegetarian diet index, higher intakes of all or selected plant foods received higher scores; in the healthy plant-based diet index, higher intakes of only the healthy plant foods received higher scores; in the less healthy plant-based diet index, higher intakes of only the less healthy plant foods received higher scores. In all indexes, higher intakes of animal foods received lower scores. Results from Cox proportional hazards models showed that participants in the highest versus lowest quintile for adherence to overall plant-based diet index or provegetarian diet had a 16%, 31% to 32%, and 18% to 25% lower risk of cardiovascular disease, cardiovascular disease mortality, and all-cause mortality, respectively, after adjusting for important confounders (all $P<0.05$ for trend). Higher adherence to a healthy plant-based diet index was associated with a 19% and 11% lower risk of cardiovascular disease mortality and all-cause mortality, respectively, but not incident cardiovascular disease ($P<0.05$ for trend). No associations were observed between the less healthy plant-based diet index and the outcomes.

***Conclusions*—**Diets higher in plant foods and lower in animal foods were associated with a lower risk of cardiovascular morbidity and mortality in a general population. **(*J Am Heart Assoc*. 2019;8:e012865. DOI: 10.1161/JAHA.119.012865.)**

Key Words: cardiovascular disease • diet • morbidity/mortality • vegetation

Plant-based diets are dietary patterns that emphasize higher intakes of plant foods and are low in animal foods. Vegetarian diets, a type of plant-based diet, with a focus on restriction of different types of animal foods (meat, poultry, or fish), have been associated with a lower risk of cardiovascular risk factors, such as obesity, hypertension, type 2 diabetes mellitus, and ischemic heart disease.[1–3] However, prospective cohort studies have shown mixed results on the associations with cardiovascular disease mortality and all-cause mortality.[4–6] These previous studies were conducted in selected study populations that were mostly composed of Seventh-Day Adventists, vegetarians, or health-conscious individuals; thus, they had relatively narrow generalizability.[4,5,7–9]

Although prior studies have characterized participants' diets using a relatively simple classification method based on frequency of animal food consumption,[4–6] there have since been more comprehensive attempts to assess an individual's diet using plant-based diet indexes.[10–13] These indexes give higher scores for higher consumption of plant foods and lower consumption of animal foods, allowing researchers to examine whether the degree of adherence to an overall plant-based diet is associated with health outcomes. Studies that used such indexes (ie, an overall plant-based diet index [PDI] or a provegetarian diet index) found that greater adherence to these diets was

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Accompanying Data S1, Tables S1 through S6, and Figures S1 through S5 are available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.119.012865

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Clinical Perspective

What Is New?

- Plant-based diets, diets that emphasize higher intakes of plant foods and lower intakes of animal foods, are associated with a lower risk of incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality in a general US adult population.
- Healthful plant-based diets, diets higher in nutrient-dense plant foods and lower in refined carbohydrates and animal foods, are associated with a lower risk of cardiovascular disease mortality and all-cause mortality, but not incident cardiovascular disease.

What Are the Clinical Implications?

- Our results suggest that dietary patterns that are relatively higher in plant foods and relatively lower in animal foods may confer benefits for cardiovascular health.
- Future research examining whether the quality of plant foods (healthful versus less healthful) within the framework of an overall plant-based diet is associated with cardiovascular disease and all-cause mortality is warranted.

associated with a lower risk of type 2 diabetes mellitus, coronary heart disease, and all-cause mortality.[10–12] In addition, some plant-based indexes separately scored healthful (whole grains, vegetables, and plant proteins) and unhealthful (refined carbohydrates and sugar) plant sources of food. Healthful plant-based diets, which scored higher intakes of only healthful plant foods higher, were more strongly inversely associated with type 2 diabetes mellitus and coronary heart disease than the overall plant-based diets.[11,12] In contrast, greater adherence to less healthful (unhealthful) plant-based diets, which scored higher intakes of only less healthful plant foods higher, were associated with a higher risk of these conditions.[11,12]

Given the limited evidence on plant-based diets in the general population and recent developments in plant-based diet scores, the objectives of the present study were as follows: (1) to evaluate whether overall plant-based diets are associated with a lower risk of incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality in a general US population; and (2) to assess if the association differed by adherence to healthful and less healthful plant-based diets using 4 a priori defined plant-based diet scores (overall plant-based diet, healthy plant-based diet, less healthy plant-based diet, and provegetarian diet indexes).

Methods

ARIC (Atherosclerosis Risk in Communities) study data are available through the National Heart, Lung, and Blood Institute Biologic Specimen and Data Repository Information Coordinating Center. Interested researchers may also contact the ARIC study Coordinating Center to access data and study materials.

Study Design

We used data from a community-based cohort of middle-aged men and women (45–64 years of age at baseline, n=15 792) in the ARIC study. From 1987 to 1989, participants from 4 US communities (Washington County, Maryland; Forsyth County, North Carolina; Minneapolis, MN; and Jackson, MS) were enrolled in the study.[14] Follow-up visits occurred in 1990 to 1992 (visit 2), 1993 to 1995 (visit 3), 1996 to 1998 (visit 4), 2011 to 2013 (visit 5), and 2016 to 2017 (visit 6).[14] The Institutional Review Board at each study site approved the study protocol, and participants provided informed consent.

Dietary Assessment

At baseline and visit 3, participants' usual intake of foods and beverages was assessed by trained interviewers using a modified version of the 66-item semiquantitative Willett food frequency questionnaire.[15] Participants indicated the frequency with which they consumed foods and beverages of a defined serving size in the previous year. Visual guides, such as glasses and measuring cups, were provided for participants to estimate portion size. The reliability of the food frequency questionnaire was assessed in a random sample of ARIC study participants (n=419) from all 4 study sites at visit 2.[15] Nutrient and total energy intakes were derived through multiplying consumption of food by nutrient content of each item in the food frequency questionnaire.

Plant-Based Diet Scores

The ARIC study did not assess whether participants were following a plant-based diet. We used established plant-based diet scores (PDI, healthy plant-based diet index [hPDI], less healthy [unhealthy] plant-based diet index [uPDI], and provegetarian diet index) to assess participants' degree of adherence to plant-based diets on the basis of their reported dietary intake on the food frequency questionnaire. We used these 4 plant-based diet indexes to provide comprehensive and nuanced characterization of dietary intakes because the indexes differed from each other in scoring of food groups within the indexes. For instance, the PDI was more comprehensive than the provegetarian index in that the PDI assessed dietary intakes of plant foods high in refined carbohydrates (fruit juices, sugar-sweetened beverages, sweets, and desserts). Consistent with some ethically motivated dietary patterns that are focused on the exclusion of animal sources of food and have less of an

emphasis on the quality of plant foods, the provegetarian diet index provides a more simplistic score of the diet in that these refined carbohydrate food groups were not assessed. Further details on differences and construction of the scores have been published previously and are available in Data S1.[10–13,16]

The PDI, hPDI, and uPDI had a possible range from 17 to 85, and the provegetarian diet index had a possible range from 11 to 55. All scores were divided into quintiles for analyses.

Outcome Assessment

Incident cardiovascular disease events and deaths (cardiovascular and all cause) were ascertained through annual telephone calls with participants or proxies, active surveillance of local hospital discharge records and state death records, and linkage to the National Death Index from baseline to December 31, 2016. Incident cardiovascular disease was defined as a composite outcome of coronary heart disease, stroke, and heart failure. Incident coronary heart disease was defined as hospitalized myocardial infarction or fatal coronary heart disease.[17] Incident stroke was defined as definite or probable stroke, which was adjudicated.[18] Incident heart failure was defined as hospitalization or death, with *International Classification of Diseases, Ninth Revision* (*ICD-9*), code 428 or *International Classification of Diseases, Tenth Revision* (*ICD-10*), code I50.[19] All-cause mortality was defined as deaths attributable to any cause, and cardiovascular disease mortality was defined as deaths with *ICD-9* codes 390 to 459 or *ICD-10* codes I00 to I99.

Covariate Assessment

At baseline, participants' sociodemographic information (age, sex, race/ethnicity, and education), health behaviors (cigarette smoking, frequency and duration of physical activity, alcohol intake, and margarine intake), medication use (lipid-lowering medication use, antihypertensive medication use, or diabetes mellitus medication use), and health conditions (diagnosis of diseases) were collected by self-reports.

Trained staff measured participants' weight and height, which was used to calculate body mass index (BMI; kg/m^2). Those whose BMI was ≤25 kg/m^2 were classified as normal weight, those whose BMI was from 25 to <30 kg/m^2 were classified as overweight, and those whose BMI was ≥30 kg/m^2 were classified as obese. An enzymatic method was used to measure total cholesterol concentration.[20] A certified technician measured participants' blood pressure 3 times, and the second and third measurements were averaged. The modified hexokinase/glucose-6-phosphate dehydrogenase method was used to measure blood glucose concentrations. Baseline kidney function (estimated glomerular filtration rate) was estimated from serum creatinine measurement using the 2009 Chronic Kidney Disease Epidemiology Collaboration equation.[21] We defined hypertension as systolic blood pressure of ≥140 mm Hg, diastolic blood pressure of ≥90 mm Hg, or antihypertensive medication use in the past 2 weeks. We defined diabetes mellitus as fasting glucose concentration of ≥126 mg/dL, nonfasting blood glucose concentration of ≥200 mg/dL, self-reported physician's diagnosis of diabetes mellitus, or diabetes mellitus medication use in the past 2 weeks.

Statistical Analyses

We calculated dietary intakes from baseline and visit 3 using cumulative averaged diet with respect to each outcome.[22] For example, we used dietary intake from only visit 1 if participants developed cardiovascular disease or were censored before visit 3. We averaged the dietary intake from both visits if participants developed cardiovascular disease or were censored after visit 3.

To create the final analytic sample of 12 168, we first excluded participants with implausible total energy intake (<500 or >3500 kcal for women and <700 or >4500 kcal for men, n=383). Then, we excluded those whose race/ethnicity was neither black nor white (n=47), blacks in Minnesota (n=18), and blacks in Maryland (n=23). We also excluded participants with a history of myocardial infarction, heart or arterial surgery, heart failure, stroke, and cancer at baseline because diagnosis of these conditions may change dietary habits (n=2677). Participants without complete information on covariates were excluded from analyses as well (n=476).

Baseline characteristics of the study participants and nutritional characteristics of the diet were examined according to quintiles of plant-based diet scores (PDI, hPDI, uPDI, and provegetarian diet index) using χ^2 tests for categorical variables and ANOVA for continuous variables. Food intakes were expressed as servings per day, macronutrients as a percentage of energy, and fiber and micronutrients as g, mg, or μg per 1000 kcal.

We calculated hazard ratios (HRs) and 95% CIs to estimate the association between plant-based diet scores and incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality. Three nested Cox proportional hazards models were modeled using length of follow-up time as the time metric. In model 1, total energy intake, age, sex, and race-center (whites in Washington County, Maryland; blacks in Forsyth County, North Carolina; whites in Forsyth County, North Carolina; whites in Minneapolis, MN; and blacks in Jackson, MS) were adjusted. In model 2, education (a proxy for socioeconomic status), cigarette smoking, physical activity, alcohol intake, and margarine intake were additionally adjusted. In model 3, potential mediating variables, such as total cholesterol, lipid-lowering medication use, hypertension,

diabetes mellitus, baseline kidney function (2 linear spline terms with 1 knot at 90 mL/min per 1.73 m^2), and BMI were additionally adjusted. We evaluated the proportionality assumption by examining Schoenfeld residual and log(−log) plots, and we did not find a clear indication that the assumption was violated. The median value within each quintile of plant-based diet scores was used to test for a linear trend. We considered the main results to be estimates from model 2 (no potential mediating variables). In addition, we used splines to visually depict the relation between plant-based diet scores as a continuous variable and incident cardiovascular disease. We first used restricted cubic splines with 4 knots at the 5th, 35th, 65th, and 95th percentiles. The shape of the association appeared approximately linear, so we presented the results using 2 linear spline terms with 1 knot at the 12.5th percentile of each plant-based diet index. As a sensitivity analysis, we considered margarine as part of the plant-based diet scores instead of a covariate in the fully adjusted models. Margarine intake was positively scored in the PDI, hPDI, and provegetarian diet index and negatively scored in the uPDI, consistent with how vegetable oil was scored in previous studies.[10–12]

We conducted 2 additional analyses in model 3: First, we modeled score components of plant-based diet scores (healthy plant foods [aggregated consumption of whole grains, fruits, vegetables, nuts, legumes, tea, and coffee], less healthy plant foods [aggregated consumption of fruits juices, refined grain, potatoes, sugar-sweetened beverages, sweets, and desserts], and animal foods [aggregated consumption of animal fat, dairy, eggs, fish or seafood, meat, and miscellaneous animal foods] from PDI; plant foods [selected] and animal foods from provegetarian diet index) simultaneously instead of the scores. Second, we modeled the individual food groups within PDI and provegetarian diet index simultaneously. Given that associations with red and processed meat differ from poultry with regard to cardiovascular disease and all-cause mortality,[23] we reclassified the meat category into 2 separate categories: (1) red and processed meat and (2) poultry. Third, we examined whether the observed associations differed by sex (women/men), age (less than the median, greater than or equal to the median), race (white or black), weight status (normal weight, overweight, or obese), and diabetes mellitus status (diabetes mellitus or no diabetes mellitus). All analyses were conducted using Stata, version 13.0, statistical software (StataCorp, College Station, TX).

Results

Baseline Characteristics

The PDI ranged from 28 to 74, the hPDI ranged from 29 to 77, the uPDI ranged from 27 to 76, and the provegetarian diet index ranged from 15 to 54. Those in the highest quintiles of PDI, hPDI, and provegetarian diet index were more likely to be women, white, high school graduates, and physically active and were less likely to be obese, to be current smokers, to have diabetes mellitus, and to have hypertension at baseline compared with those in the lowest quintiles (Tables 1 and 2, Table S1). Conversely, those in the highest quintile of uPDI were more likely to be men, to be younger, to be current smokers, and to drink a higher amount of alcohol and less likely to be high school graduates, obese, and physically active compared with those in the lowest quintile. Those in the highest quintile of uPDI were more likely to have hypertension, but less likely to have diabetes mellitus ($P<0.05$ for all comparisons) (Table S2).

Nutritional Characteristics

Participants in the highest quintiles of PDI, hPDI, and provegetarian diet index consumed an average of 4.1 to 4.8 servings of fruit and vegetables per day and 0.8 to 0.9 servings of red and processed meat per day (Tables 1 and 2, Table S1). Those in the highest quintiles of PDI, hPDI, and provegetarian diet had higher intake of carbohydrates and plant protein as a percentage of energy, fiber, and micronutrients, including potassium, magnesium, iron, vitamin A, vitamin C, and folate, and lower intake of saturated fat and cholesterol compared with those in the lower quintiles ($P<0.05$ for all comparisons). Polyunsaturated fat as a percentage of energy was higher among those in the highest quintiles of PDI and provegetarian diet, but lower among those in the highest quintiles of hPDI and uPDI ($P<0.05$ for all comparisons).

In contrast, those in the highest quintile of uPDI consumed an average of 2.3 servings of fruit and vegetables per day and 1.2 servings of red and processed meat per day (Table S2). Those in the highest quintile of uPDI consumed higher intake of total energy and carbohydrates as a percentage of energy, but had lower intake of fiber and micronutrients, including calcium, potassium, magnesium, iron, vitamin A, vitamin C, and folate compared with those in the lowest quintile of uPDI ($P<0.05$ for all comparisons).

Plant-Based Diets and Cardiovascular Disease Outcomes and All-Cause Mortality

During a median follow-up of 25 years, 4381 incident cardiovascular disease events, 1565 deaths caused by cardiovascular disease, and 5436 deaths attributable to all causes occurred. Incidence rates for cardiovascular disease events, cardiovascular disease mortality, and all-cause mortality were lower at higher quintiles of PDI, hPDI, and provegetarian diet index (Table S3). We did not observe a strong and consistent pattern for incidence rates of the outcomes across quintiles of uPDI. There was a significant lower risk of incident

Table 1. Selected Baseline Characteristics and Nutritional Characteristics by Quintiles of the PDI in the ARIC Study

Characteristic	PDI (n=12 168)				
	Quintile 1 (n=2717)	Quintile 2 (n=2864)	Quintile 3 (n=2308)	Quintile 4 (n=1992)	Quintile 5 (n=2287)
Score, median (range)	44 (28–46)	49 (47–50)	52 (51–53)	55 (54–56)	59 (57–74)
Women, %*	42.3	55.2	60.0	61.5	60.6
Black, %*	43.2	31.3	24.1	19.2	12.9
Age, y*	53.7 (5.8)	53.7 (5.6)	53.7 (5.7)	54.2 (5.7)	53.9 (5.8)
High school graduate, %*	68.3	75.8	78.7	82.6	85.1
BMI category, %*					
Normal weight (<25 kg/m^2)	19.5	21.7	18.9	16.9	22.8
Overweight (25–<30 kg/m^2)	22.6	24.4	18.4	17.2	17.3
Obese (≥30 kg/m^2)	27.5	24.7	19.4	13.7	14.6
Current smoker, %*	33.8	27.8	23.2	19.2	19.2
Physical activity index*	2.3 (0.7)	2.4 (0.8)	2.4 (0.8)	2.5 (0.8)	2.6 (0.8)
Alcohol, g/wk*	68.9 (137.9)	45.2 (95.2)	36.4 (80.7)	32.4 (66.3)	28.6 (59.4)
Fasting glucose, mg/dL*	110.3 (42.4)	109.4 (42.7)	107.3 (37.8)	105.4 (32.2)	102.9 (29.1)
Diabetes mellitus, %*	11.5	11.4	10.5	9.4	7.0
Hypertension, %*	36.5	32.3	31.2	30.6	27.0
Lipid-lowering medication, %*	1.2	1.3	2.5	3.4	3.8
eGFR, mL/min per 1.73 m^{2}*	105.2 (16.4)	103.3 (15.8)	102.9 (14.9)	102.1 (13.9)	101.9 (13.2)
Food and nutrient intake per day*					
Healthy plant foods†	5.4 (2.8)	6.3 (2.9)	7.0 (2.9)	7.7 (2.8)	9.0 (3.0)
Less healthy plant foods†	4.6 (2.3)	4.7 (2.4)	4.9 (2.4)	5.1 (2.4)	6.0 (2.6)
Animal foods†	5.6 (2.3)	4.5 (2.0)	4.0 (1.8)	3.8 (1.7)	3.6 (1.8)
Fruit and vegetables†	2.8 (1.7)	2.8 (1.7)	3.1 (1.7)	3.5 (1.7)	4.1 (1.9)
Red and processed meats†	1.5 (0.8)	1.2 (0.7)	1.0 (0.7)	0.9 (0.6)	0.8 (0.7)
Dairy†	1.8 (1.4)	1.6 (1.2)	1.5 (1.1)	1.5 (1.1)	1.5 (1.0)
Fish or seafood†	0.3 (0.3)	0.3 (0.3)	0.3 (0.3)	0.3 (0.3)	0.2 (0.3)
Margarine†	1.0 (0.9)	1.0 (0.9)	1.0 (0.9)	1.1 (1.0)	1.1 (0.9)
Total energy, kcal	1715 (593)	1569 (555)	1548 (537)	1573 (524)	1698 (521)
Total protein, % of energy	18.7 (3.9)	18.5 (3.9)	18.3 (3.7)	17.9 (3.5)	17.0 (3.1)
Animal protein, % of energy	15.2 (3.9)	14.4 (3.8)	13.8 (3.6)	13.0 (3.4)	11.6 (3.2)
Plant protein, % of energy	3.6 (0.8)	4.2 (0.9)	4.6 (0.9)	4.9 (1.0)	5.3 (1.1)
Carbohydrates, % of energy	43.7 (8.0)	47.4 (7.8)	50.0 (7.4)	52.1 (7.2)	54.6 (7.2)
Total fat, % of energy	35.4 (5.9)	33.3 (5.7)	32.0 (5.7)	30.7 (5.8)	29.8 (5.6)
Saturated fat, % of energy	13.2 (2.7)	12.2 (2.4)	11.5 (2.3)	10.9 (2.3)	10.3 (2.3)
MUFA, % of energy	13.9 (2.6)	13.0 (2.6)	12.4 (2.5)	11.9 (2.7)	11.5 (2.6)
PUFA, % of energy	4.9 (1.2)	4.9 (1.2)	4.9 (1.2)	4.9 (1.2)	5.0 (1.2)
Fiber, g/1000 kcal	8.3 (2.7)	10.1 (3.0)	11.4 (3.3)	12.3 (3.4)	13.4 (3.5)
Cholesterol, mg/1000 kcal	194.6 (61.8)	166.4 (49.0)	150.2 (40.6)	135.9 (37.7)	118.4 (33.7)
Sodium, mg/1000 kcal	892.7 (175)	912.7 (179)	934.9 (181)	939.6 (175)	952.4 (168)
Phosphorous, mg/1000 kcal	663.5 (155)	674.9 (153)	681.0 (146)	682.1 (140)	664.7 (127)
Calcium, mg/1000 kcal	404.7 (183)	410.0 (169)	413.2 (154)	418.4 (151)	398.8 (132)

Continued

Table 1. Continued

Characteristic	PDI (n=12 168)				
	Quintile 1 (n=2717)	Quintile 2 (n=2864)	Quintile 3 (n=2308)	Quintile 4 (n=1992)	Quintile 5 (n=2287)
Potassium, mg/1000 kcal	1485 (347)	1635 (364)	1717 (371)	1786 (369)	1807 (338)
Magnesium, mg/1000 kcal	142.8 (33.6)	156.5 (35.2)	164.0 (35.7)	169.9 (35.8)	174.5 (34.7)
Iron, mg/1000 kcal	6.5 (1.7)	7.0 (2.0)	7.3 (2.2)	7.4 (2.1)	7.7 (2.3)
Vitamin A, IU/1000 kcal	4917 (3176)	5803 (3616)	6359 (4182)	6674 (4151)	7005 (4050)
Vitamin C, mg/1000 kcal	61.5 (35.8)	73.9 (38.4)	82.5 (40.1)	89.6 (41.4)	93.8 (39.3)
Folate, μg/1000 kcal	126.2 (42.0)	145.4 (48.2)	157.3 (51.2)	167.9 (53.8)	173.9 (51.0)
Vitamin B12, μg/1000 kcal	5.2 (2.4)	4.9 (2.3)	4.7 (2.2)	4.2 (2.0)	3.7 (1.7)
Zinc, mg/1000 kcal	6.8 (1.5)	6.8 (1.6)	6.7 (1.5)	6.6 (1.5)	6.4 (1.3)

Values are means (SDs) for continuous variables and percentages for categorical variables. ARIC indicates Atherosclerosis Risk in Communities; BMI, body mass index; eGFR, estimated glomerular filtration rate; IU, international units; MUFA, monounsaturated fatty acid; PDI, overall plant-based diet index; PUFA, polyunsaturated fatty acid.
*Indicates a statistical difference by quintiles of PDI ($P<0.05$), tested using ANOVA for continuous variables and χ^2 test for categorical variables.
†Food intakes are expressed as servings per day.

cardiovascular disease, cardiovascular disease mortality, and all-cause mortality across quintiles of PDI, hPDI, and provegetarian diet index only in the minimally adjusted models that accounted for age, sex, race-center, and total energy intake.

The strongest and most consistent significant associations were observed for PDI and provegetarian diet index, with all 3 outcomes in all 3 models (Figures S1 and S2). After adjusting for sociodemographic characteristics (age, sex, race-center, and education), dietary factors (total energy intake and margarine consumption), and health behaviors (smoking, physical activity, and alcohol consumption), those in the highest versus lowest quintiles of PDI and provegetarian diet index had a 16% and 16% lower risk of incident cardiovascular disease, a 32% and 31% lower risk of cardiovascular mortality, and a 25% and 18% lower risk of all-cause mortality, respectively (Table 3). These associations remained significant and similar in magnitude after adjusting for potential mediating factors (total cholesterol, lipid-lowering medication use, estimated glomerular filtration rate, hypertension, diabetes mellitus, and BMI) (Table S4). In the continuous analysis, there was an approximately linear inverse relationship between PDI (Figure 1) and provegetarian diet index (Figure 2) scores and risk of incident cardiovascular disease.

For hPDI, after adjusting for sociodemographic characteristics, dietary factors, and health behaviors in model 2, those in the highest versus lowest quintile had a 19% lower risk of cardiovascular disease mortality (HR, 0.81; 95% CI, 0.68–0.97; P=0.01 for trend) and an 11% lower risk of all-cause mortality (HR, 0.89; 95% CI, 0.81–0.98; P=0.01 for trend) (Table 3). After accounting for potential mediating factors in model 3, there was still a significant inverse trend for cardiovascular disease mortality and all-cause mortality across quintiles of hPDI (P=0.03 for trend for both) (Table S4). However, we found no significant association between hPDI and incident cardiovascular disease in model 2 (Table 3) or model 3 (Table S4).

No significant associations were observed between uPDI and the outcomes in model 1 (Table S3), model 2 (Table 3), or model 3 (Table S4) (all P>0.05 for trend). Similar results were observed when we used hPDI and uPDI as continuous variables (Figures S3 and S4).

When margarine was included as part of the scores, the association between provegetarian diet and incident cardiovascular disease was attenuated ($HR_{\text{quintile 5 versus quintile 1}}$, 0.89; 95% CI, 0.81–1.00; P=0.01 for trend). The results were similar to those from the main analysis for all other indexes.

Analyses on Score Components and Individual Food Groups

When we modeled score components of PDI (quintiles of healthy plant food, less healthy plant food, and animal food) simultaneously instead of the overall score in model 3, those in the highest quintile of animal food consumption had a higher risk of incident cardiovascular disease (HR, 1.14; 95% CI, 1.04–1.27; P<0.001 for trend), cardiovascular disease mortality (HR, 1.30; 95% CI, 1.10–1.54; P<0.001 for trend), and all-cause mortality (HR, 1.12; 95% CI, 1.02–1.23; P=0.001 for trend) compared with those in the lowest quintile, whereas no significant association was observed for healthy plant food or less healthy plant food consumption (Table S5). When components of the provegetarian diet index (quintiles of selected plant foods and animal foods) were modeled, similar associations with animal foods were observed for all 3 outcomes (all P<0.01 for trend). A higher intake of selected plant food in the provegetarian diet index was associated with

Table 2. Selected Baseline Characteristics and Nutritional Characteristics by Quintiles of the Provegetarian Diet Index in the ARIC Study

Characteristic	Provegetarian Diet Index (n=12 168)				
	Quintile 1 (n=2970)	Quintile 2 (n=2687)	Quintile 3 (n=1911)	Quintile 4 (n=2266)	Quintile 5 (n=2334)
Score, median (range)	27 (15–29)	31 (30–32)	33 (33–34)	36 (35–37)	40 (38–54)
Women, %*	46.5	55.7	59.2	59.5	58.4
Black, %*	35.5	31.7	27.9	21.5	16.5
Age, y*	53.4 (5.7)	53.7 (5.7)	53.6 (5.7)	54.0 (5.7)	54.6 (5.8)
High school graduate, %*	72.4	76.6	77.2	79.4	83.4
BMI category, %*					
Normal weight (<25 kg/m^2)	21.8	19.8	15.4	20.3	22.7
Overweight (25–<30 kg/m^2)	24.3	23.1	16.1	18.3	18.2
Obese (≥30 kg/m^2)	28.9	24.2	15.4	16.5	18.9
Current smoker, %*	32.9	27.3	24.0	22.8	16.8
Physical activity index*	2.3 (0.8)	2.4 (0.8)	2.4 (0.8)	2.5 (0.8)	2.6 (0.8)
Alcohol, g/wk*	60.3 (123.4)	43.1 (89.3)	39.4 (87.9)	38.9 (91.1)	31.4 (68.5)
Fasting glucose, mg/dL*	109.1 (41.1)	109.9 (43.3)	106.8 (36.3)	105.4 (33.0)	104.4 (32.2)
Diabetes mellitus, %*	10.4	11.6	10.2	9.8	8.2
Hypertension, %*	34.1	31.4	32.2	31.4	29.4
Lipid-lowering medication, %*	1.1	1.7	2.3	2.9	3.9
eGFR, mL/min per 1.73 m^2*	104.5 (15.9)	103.7 (15.5)	103.3 (15.3)	102.5 (14.3)	101.6 (13.6)
Food and nutrient intake per day*					
Healthy plant foods†	5.5 (2.7)	6.3 (2.8)	6.9 (2.8)	7.5 (2.9)	9.0 (3.1)
Less healthy plant foods†	4.7 (2.3)	4.8 (2.4)	4.9 (2.4)	5.2 (2.5)	5.6 (2.6)
Animal foods†	5.2 (2.3)	4.4 (2.0)	4.2 (1.9)	4.0 (1.8)	3.7 (1.8)
Fruit and vegetables†	2.1 (1.4)	2.7 (1.6)	3.1 (1.6)	3.6 (1.7)	4.5 (2.0)
Red and processed meat†	1.4 (0.8)	1.2 (0.8)	1.0 (0.7)	1.0 (0.7)	0.9 (0.7)
Dairy†	1.8 (1.3)	1.6 (1.2)	1.6 (1.2)	1.5 (1.1)	1.5 (1.0)
Fish or seafood†	0.3 (0.3)	0.3 (0.3)	0.3 (0.3)	0.3 (0.3)	0.2 (0.3)
Margarine†	1.0 (0.9)	1.0 (0.9)	1.0 (0.9)	1.1 (0.9)	1.2 (1.0)
Total energy intake, kcal	1618 (585)	1567 (561)	1574 (551)	1619 (527)	1739 (514)
Protein, % of energy	18.7 (4.0)	18.4 (3.9)	18.2 (3.7)	17.8 (3.6)	17.4 (3.2)
Animal protein, % of energy	15.2 (4.0)	14.3 (3.8)	13.7 (3.6)	13.0 (3.5)	11.9 (3.3)
Plant protein, % of energy	3.5 (0.8)	4.2 (0.8)	4.5 (0.9)	4.8 (0.9)	5.5 (1.1)
Carbohydrates, % of energy	44.3 (8.1)	47.7 (7.9)	49.7 (7.6)	51.6 (7.5)	54.4 (7.4)
Total fat, % of energy	35.2 (5.8)	33.3 (5.7)	32.2 (5.7)	31.0 (5.8)	29.5 (5.8)
Saturated fat, % of energy	13.2 (2.6)	12.2 (2.4)	11.6 (2.3)	11.0 (2.3)	10.1 (2.2)
MUFA, % of energy	13.8 (2.5)	13.0 (2.6)	12.5 (2.6)	12.0 (2.6)	11.5 (2.7)
PUFA, % of energy	4.8 (1.1)	4.9 (1.2)	4.9 (1.2)	5.0 (1.2)	5.1 (1.2)
Fiber, g/1000 kcal	8.0 (2.3)	10.0 (2.7)	11.3 (3.0)	12.2 (3.1)	14.1 (3.6)
Cholesterol, mg/1000 kcal	191.1 (60.3)	166.3 (48.3)	151.7 (44.9)	137.2 (39.1)	119.8 (35.0)
Sodium, mg/1000 kcal	882.8 (169)	908.4 (173)	923.2 (178)	939.4 (174)	981.7 (178)
Phosphorous, mg/1000 kcal	672.5 (157)	672.0 (149)	675.0 (144)	671.8 (143)	672.7 (129)

Continued

Table 2. Continued

Characteristic	Provegetarian Diet Index (n=12 168)				
	Quintile 1 (n=2970)	Quintile 2 (n=2687)	Quintile 3 (n=1911)	Quintile 4 (n=2266)	Quintile 5 (n=2334)
Calcium, mg/1000 kcal	414 (182.1)	405.8 (162)	410.0 (158)	409.6 (155)	401.5 (135)
Potassium, mg/1000 kcal	1534 (361)	1635 (375)	1708 (380)	1740 (363)	1802 (342)
Magnesium, mg/1000 kcal	146.7 (34.3)	156.6 (35.9)	163.2 (36.8)	166.1 (35.2)	174.1 (35.5)
Iron, mg/1000 kcal	6.4 (1.7)	7.0 (2.1)	7.2 (2.1)	7.5 (2.2)	7.8 (2.3)
Vitamin A, IU/1000 kcal	4677 (2881)	5734 (3573)	6286 (4052)	6741 (4047)	7442 (4383)
Vitamin C, mg/1000 kcal	66.1 (37.6)	75.9 (40.3)	81.9 (41.9)	85.7 (40.2)	90.1 (38.9)
Folate, μg/1000 kcal	129.2 (43.6)	146.2 (48.7)	157.4 (55.8)	162.3 (49.5)	175.0 (51.3)
Vitamin B12, μg/1000 kcal	5.1 (2.4)	5.0 (2.4)	4.6 (2.2)	4.3 (2.0)	3.8 (1.8)
Zinc, mg/1000 kcal	6.8 (1.6)	6.8 (1.6)	6.7 (1.5)	6.5 (1.4)	6.4 (1.3)

Values are means (SDs) for continuous variables and percentages for categorical variables. ARIC indicates Atherosclerosis Risk in Communities; BMI, body mass index; eGFR, estimated glomerular filtration rate; IU, international units; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.
*Indicates statistical difference by quintiles of provegetarian diet index ($P<0.05$), tested using ANOVA for continuous variables and χ^2 test for categorical variables.
†Food intakes are expressed as servings per day.

a lower risk of cardiovascular disease mortality ($P=0.009$ for trend) and all-cause mortality ($P<0.001$ for trend), but the association between selected plant food in the provegetarian diet index and cardiovascular disease was not statistically significant (HR, 0.95; 95% CI, 0.86–1.05; $P=0.05$ for trend).

When we modeled all food groups in the PDI simultaneously, higher intakes of whole grains were consistently associated with a lower risk of incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality, whereas higher intakes of eggs and red and processed meat were associated with a higher risk of all 3 outcomes (Table S6). Higher intake of potatoes, which were classified as less healthy plant foods for hPDI and uPDI, was inversely associated with incident cardiovascular disease and all-cause mortality. There was no significant association for dairy or for fish and seafood with all 3 outcomes. Similar associations between individual food components of the provegetarian diet index (specifically, eggs, red and processed meat, potatoes, dairy, and fish or seafood) were observed.

Subgroup Analyses

For incident cardiovascular disease, we found evidence of statistical interaction by diabetes mellitus status with hPDI ($P=0.01$ for interaction) and provegetarian diet ($P=0.03$ for interaction) (Figure S5). The associations for hPDI and provegetarian diet with risk of incident cardiovascular disease were stronger among those with diabetes mellitus relative to those without diabetes mellitus, although hPDI was not significantly associated with cardiovascular disease in either subgroup. No statistical evidence of interaction was observed by sex, age, race, or weight status with incident cardiovascular disease. There was also no statistical interaction by sex, age, race, weight status, or diabetes mellitus status with cardiovascular disease mortality and all-cause mortality for all indexes ($P>0.05$ for interaction for all tests).

Discussion

In this community-based cohort of US adults without cardiovascular disease at baseline, we found that higher adherence to an overall plant-based diet or a provegetarian diet, diets that are higher in plant foods and lower in animal foods, was associated with a lower risk of incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality. Healthy plant-based diets, which are higher in whole grains, fruits, vegetables, nuts, legumes, tea, and coffee and lower in animal foods, were associated with a lower risk of cardiovascular disease mortality and all-cause mortality.

Our study is one of the few studies that used data from a general population. Prospective studies of Seventh-Day Adventists in the United States and Canada found that vegetarians had a lower risk of cardiovascular disease mortality and all-cause mortality compared with nonvegetarians.[4] The EPIC (European Prospective Investigation Into Cancer and Nutrition)-Oxford study of vegetarians, vegans, and health-conscious individuals reported that the risk of incident ischemic heart disease and deaths caused by circulatory disease was lower in vegetarians than nonvegetarians.[5,24] However, these findings were not replicated in population-based studies in Australia and the United States.[6,13] Notably, a prior study that used data from a

Table 3. Hazard Ratios and 95% CIs for Incident Cardiovascular Disease, Cardiovascular Disease Mortality, and All-Cause Mortality, According to Quintiles of Plant-Based Diet Indexes

Variable	Quintile	Hazard Ratios (95% CIs)		
		Incident Cardiovascular Disease	Cardiovascular Disease Mortality	All-Cause Mortality
No. of events	. . .	4381	1565	5436
PDI	1	1 (Reference)	1 (Reference)	1 (Reference)
	2	0.98 (0.89–1.08)	0.85 (0.74–0.99)	0.89 (0.82–0.96)
	3	0.96 (0.88–1.04)	0.81 (0.71–0.93)	0.83 (0.77–0.89)
	4	0.86 (0.78–0.96)	0.74 (0.63–0.87)	0.82 (0.75–0.89)
	5	0.84 (0.75–0.92)	0.68 (0.58–0.80)	0.75 (0.69–0.82)
	P value for trend	<0.001	<0.001	<0.001
hPDI	1	1 (Reference)	1 (Reference)	1 (Reference)
	2	1.01 (0.93–1.11)	0.97 (0.84–1.12)	0.99 (0.92–1.08)
	3	0.99 (0.91–1.09)	0.95 (0.82–1.11)	0.97 (0.89–1.05)
	4	1.01 (0.91–1.11)	0.83 (0.70–0.99)	0.92 (0.84–1.01)
	5	0.91 (0.82–1.01)	0.81 (0.68–0.97)	0.89 (0.81–0.98)
	P value for trend	0.11	0.01	0.01
uPDI	1	1 (Reference)	1 (Reference)	1 (Reference)
	2	0.93 (0.85–1.02)	0.95 (0.83–1.10)	1.01 (0.94–1.10)
	3	0.99 (0.91–1.09)	0.91 (0.78–1.05)	0.94 (0.87–1.02)
	4	1.02 (0.94–1.12)	0.82 (0.71–0.96)	0.95 (0.88–1.03)
	5	0.94 (0.85–1.04)	0.93 (0.80–1.08)	0.94 (0.87–1.03)
	P value for trend	0.98	0.13	0.10
Provegetarian diet index	1	1 (Reference)	1 (Reference)	1 (Reference)
	2	0.94 (0.87–1.03)	0.90 (0.79–1.03)	0.92 (0.85–0.99)
	3	0.85 (0.77–0.94)	0.78 (0.67–0.91)	0.89 (0.82–0.97)
	4	0.90 (0.82–0.99)	0.83 (0.72–0.96)	0.84 (0.78–0.91)
	5	0.84 (0.76–0.93)	0.69 (0.59–0.81)	0.82 (0.76–0.89)
	P value for trend	<0.001	<0.001	<0.001

Data are adjusted for age, sex, race-center, total energy intake, education, smoking status, physical activity, alcohol consumption, and margarine consumption. hPDI indicates healthy plant-based diet index; PDI, overall plant-based diet index; uPDI, less healthy (unhealthy) plant-based diet index.

nationally representative sample administered a brief questionnaire that assessed the frequency with which participants consumed specific types of animal food (red meat, processed meat, poultry, or fish or seafood) to characterize participants' dietary intakes.[6] Such dietary measurement may not have adequately represented dietary patterns on the basis of abundance of plant foods relative to animal foods. The plant-based diet indexes we used in this study captured a wider spectrum of intake of plant foods and animal foods, leveraging the available dietary data, and allowed us to move away from defining plant-based diets strictly based on exclusion of animal foods.

Our results on overall plant-based diets and cardiovascular disease and all-cause mortality are consistent with previous studies that used the PDI and provegetarian diet index. In a study of Spanish adults who were at high risk of developing cardiovascular disease, higher adherence to a provegetarian diet index was associated with a 53% lower risk of cardiovascular disease mortality and a 34% lower risk of all-cause mortality.[10] In a study of nurses and health professionals in the United States, higher adherence to PDI was associated with a 8% lower risk of coronary heart disease.[12] In our study, higher scores in PDI and provegetarian diet index were associated with a 16% to 24% lower risk of incident cardiovascular disease and all-cause mortality, and higher intakes of animal products were associated with an elevated risk of all of 3 outcomes. Results from our study suggest that progressively increasing the intake of plant foods by reducing the intake of animal foods is associated with benefits on cardiovascular health and mortality risk.

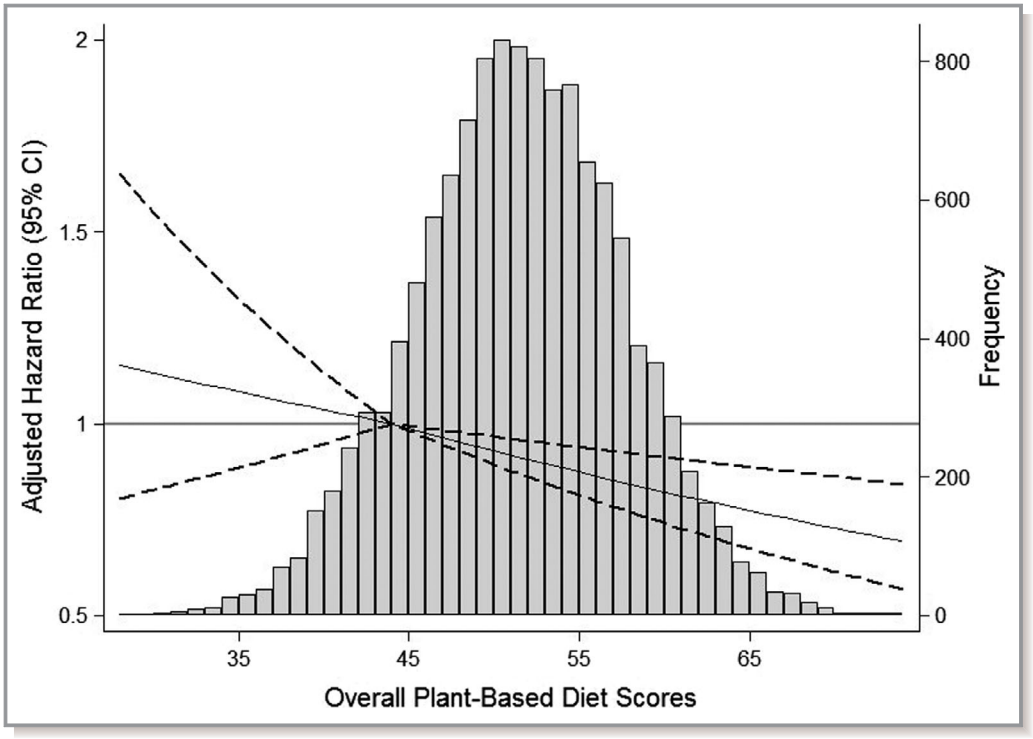

Figure 1. Adjusted hazard ratios and 95% CIs for incident cardiovascular disease, according to the continuous overall plant-based diet index (PDI). The histogram shows the distribution of scores for the PDI in gray. The solid lines represent the adjusted hazard ratios for incident cardiovascular disease, modeled using 2 linear spline terms with 1 knot at the 12.5th percentile of PDI (score, 44), which was used as the reference point. The dashed lines represent the 95% CIs. Hazard ratios were adjusted for age, sex, race-center, total energy intake, education, smoking status, physical activity, alcohol consumption, margarine consumption, baseline total cholesterol, lipid medication use, baseline kidney function, hypertension, diabetes mellitus, and baseline body mass index.

Our results on higher intakes of animal foods and higher risk of cardiovascular disease, cardiovascular disease mortality, and all-cause mortality are in line with many observational studies that reported that higher intakes of animal foods, particularly red and processed meat, are associated with an elevated risk of these outcomes.[4,5,25,26] Our results are also consistent with previous studies of vegetarian diets that characterized participants' diets on the basis of the degree of animal food consumption.[24] In our sample, those in the highest quintiles of PDI and provegetarian diet index had higher intakes of fruits and vegetables, fiber, polyunsaturated fats, and many micronutrients and lower intakes of red and processed meat and saturated fat. All these characteristics can contribute to a lower risk of cardiovascular disease by lowering blood pressure and low-density lipoprotein cholesterol, reducing inflammation, and improving glycemic control.[27–29]

However, our results diverged from a prior study that found a lower risk of coronary heart disease with an hPDI and an elevated risk with a uPDI. It is surprising that no association was observed for hPDI and cardiovascular disease in our study, given that higher intakes of foods that have been associated with a lower risk with coronary heart disease were scored higher (fruits, vegetables, whole grains, and plant proteins) in hPDI. When we modeled individual food groups within the plant-based diet indexes simultaneously, we found that foods that were considered less healthy (ie, potatoes) were inversely associated with incident cardiovascular disease and all-cause mortality. It is possible that assigning reverse scores to these foods attenuated the associations with the overall hPDI and incident cardiovascular disease. Specifically, potatoes in relation to chronic disease outcomes have shown mixed results, with recent systematic reviews concluding no association with total potato consumption and cardiovascular risk factors (obesity and type 2 diabetes mellitus), cardiovascular events, and all-cause mortality.[30,31] In the NHS (Nurses' Health Study) and HPFS (Health Professionals Follow-Up Study), higher total potato consumption was associated with a higher risk of hypertension and type 2 diabetes mellitus.[32,33] However, in 2 Spanish cohorts, no significant association between potato consumption and hypertension was observed.[34] Given these conflicting findings, future studies may consider assigning reverse scores for fried potatoes but not all potatoes.

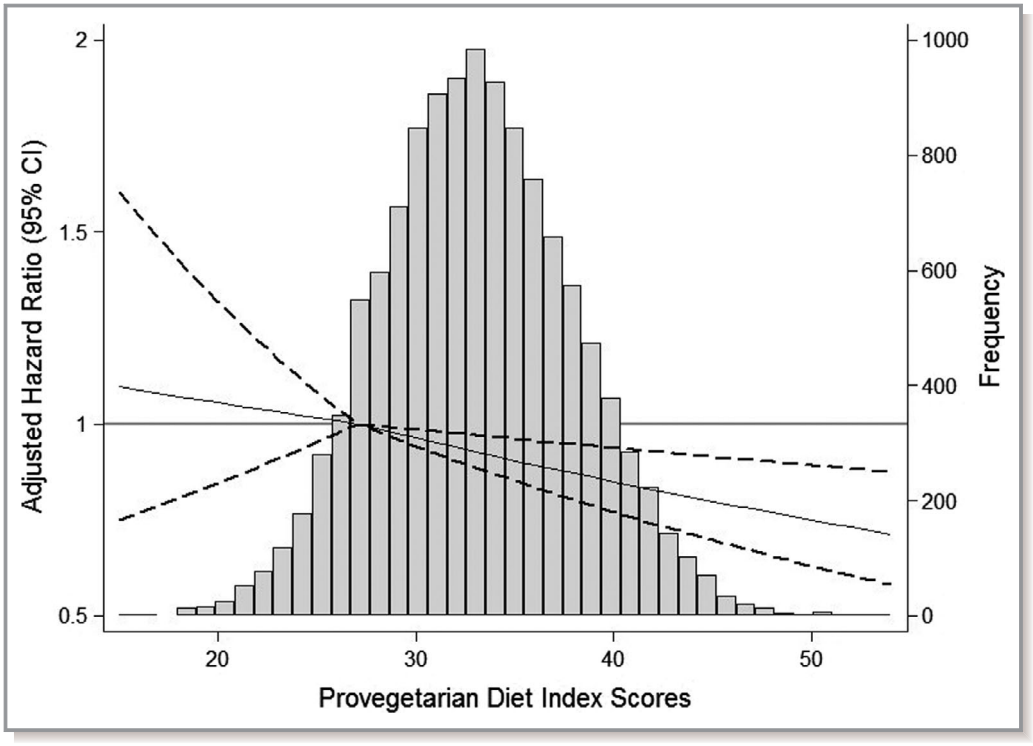

Figure 2. Adjusted hazard ratios and 95% CIs for incident cardiovascular disease, according to the continuous provegetarian diet score. The histogram shows the distribution of scores for the provegetarian diet index in gray. The solid lines represent the adjusted hazard ratios for incident cardiovascular disease, modeled using 2 linear spline terms with 1 knot at the 12.5th percentile of the provegetarian diet index (score, 27), which was used as the reference point. The dashed lines represent the 95% CIs. The hazard ratios were adjusted for age, sex, race-center, total energy intake, education, smoking status, physical activity, alcohol consumption, margarine consumption, baseline total cholesterol, lipid medication use, baseline kidney function, hypertension, diabetes mellitus, and baseline body mass index.

Unlike the NHS and HPFS, which found a higher risk of type 2 diabetes mellitus and coronary heart disease with less healthy plant-based diet scores, we found no significant associations for uPDI and incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality.[11,12] In our previous study, which used data from a nationally representative sample, we did not find associations between the uPDI and cardiovascular disease mortality and all-cause mortality.[13] It is possible that no true association exists between less healthy plant-based diets and cardiovascular disease and all-cause mortality. The lack of an association between less healthy plant-based diets and outcomes in the present study may be caused by the scoring of potatoes as a less healthy food given that we observed dietary intake of potatoes to be inversely associated with outcomes. Further research in other study populations is warranted on the health implications of diets high in refined carbohydrates and sugar and low in fruits, vegetables, and animal foods.

We found that the magnitude of association for the overall diet was stronger than the associations for the individual food components within the overall dietary pattern. These results underscore the importance of comprehensively characterizing an individual's diet, rather than assessing the intake of a single food group or nutrient. Our approach accounts for potential synergistic and interactive effects of foods and nutrients on disease risk and is in line with how plant-based diets are conceptualized (ie, higher intake of plant foods and lower intake of animal foods).[13,35–37]

When we modeled individual food groups, there was no association between dairy or fish or seafood and all 3 outcomes. Previous studies have shown that plant-rich diets that incorporated low-fat dairy products (eg, the Dietary Approaches to Stop Hypertension diet) or fish (eg, the Mediterranean-style diet) were associated with a lower risk of type 2 diabetes mellitus and cardiovascular disease.[38–41] In future studies, it may be worth exploring whether inclusion of dairy or fish in a plant-based diet is associated with a lower risk of chronic diseases.

We add to the existing literature on plant-based diets and chronic diseases by using a well-characterized community-based cohort with repeated dietary assessments and long-term follow-up. Several limitations should be accounted for when interpreting the study results. First, dietary intakes were self-reported, which is subject to measurement error.

However, the food frequency questionnaire was administered by trained interviewers, and the food frequency questionnaire has shown to have high reproducibility.[15] Second, we used a sample-based scoring method to assess the degree of adherence to plant-based diets. Those in the highest quintiles of all the plant-based diet scores had higher intakes of plant foods and lower intakes of animal foods. However, we are unable to infer if there is an absolute level of plant food or animal food intake that is associated with health outcomes. Third, dietary intakes were measured several decades ago in the ARIC study; thus, this study may not reflect the modern food supply. Studies with more recent data on plant-based diets and cardiovascular disease are warranted. Last, the possibility of residual confounding remains because of unmeasured or incorrectly measured variables.

In conclusion, diets consisting of predominantly plant foods and that are lower in animal foods were associated with a lower risk of incident cardiovascular disease, cardiovascular disease mortality, and all-cause mortality in a general population. Dietary patterns that are relatively higher in plant foods and relatively lower in animal foods may confer benefits for cardiovascular health. Considering the adverse outcomes associated with refined carbohydrate consumption,[42,43] future research should continue to explore if the quality of plant foods (either healthy plant foods or less healthy plant foods) within the framework of plant-based diets is associated with cardiovascular disease and all-cause mortality in a general population.

Author Contributions

Dr Kim wrote the manuscript and analyzed the data; Drs Kim and Rebholz designed the study; Drs Caulfield, Garcia-Larsen, Steffen, and Coresh contributed important intellectual content during drafting or revising the manuscript. Dr Rebholz was involved in all aspects of the study from analyses to writing. All authors read and approved the final manuscript.

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Disclosures

None.

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Supplemental Material

Data S1.

Expanded Methods: Plant-Based Diet Scores

For PDI, hPDI, and uPDI, we categorized food items in the food frequency questionnaire to 17 food groups, and classified these food groups to healthy plant foods (whole grains, fruits, vegetables, nuts, legumes, coffee, tea), less healthy plant foods (fruit juices, refined grain, potatoes, sugar sweetened and artificially sweetened beverages, sweets and desserts), and animal foods (animal fat, dairy, eggs, fish or seafood, meat, and miscellaneous animal foods) given their associations with chronic conditions from previous studies (1,2). Provegetarian diet index was analogous to PDI, but differed from PDI in that provegetarian diet index had 11 food groups, 6 of which were plant foods (grains, fruits, vegetables, nuts, legumes, and potatoes) and 5 were animal foods (animal fat, dairy, eggs, fish or seafood, meat). Provegetarian diet index did not score food groups such as fruit juices, potatoes, sugar sweetened and artificially sweetened beverages, sweets and desserts, and miscellaneous animal foods.

For all four plant-based diet scores, vegetable oil (margarine) was excluded, because margarine produced during this period of time may be high in *trans*-fats (1,2). We adjusted for margarine intake as a covariate. Then, we summed consumption of food items (servings/day) by food groups, and ranked participants by their energy-adjusted consumption using the residual method (3). In addition to calculating energy-adjusted consumption of food groups, we also controlled for total energy intake in our multivariable models to make isocaloric comparisons.

Details on scoring and calculation of each of the plant-based diet index are reported in our earlier publication (4). Briefly, in PDI, higher intakes of healthy plant foods and less healthy plant foods received higher scores (positive scores) whereas higher intakes of animal foods

received lower scores (reverse scores). For instance, those in the highest quintile of whole grain consumption received a score of 5, and those in the lowest quintile received a score of 1. Conversely, those in the highest quintile of animal fat consumption received a score of 1, and those in the lowest quintile received a score of 5. In hPDI, only higher intakes of healthy plant foods were positively scored. In uPDI, only higher intakes of less healthy plant foods were positively scored. In provegetarian diet index, higher intakes of plant foods (regardless of healthfulness) were positively scored, and higher intakes of animal foods were reverse scored.

Higher PDI scores represented higher intakes of healthy and less healthy plant foods. Higher hPDI scores represented higher intakes of healthy plant foods, and lower intakes of less healthy plant foods. Higher uPDI scores represented higher intakes of less healthy plant foods, and lower intakes of healthy plant foods. Higher provegetarian diet scores represented higher intakes of plant foods (regardless of healthfulness). Higher scores of all four scores represented lower intakes of animal foods.

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Table S1. Selected Baseline Characteristics and Nutritional Characteristics by Quintiles of the Healthy Plant-Based Diet Index (hPDI) in the ARIC Study*

Characteristic	Healthy Plant-Based Diet Index (n=12,168)				
	Quintile 1 (*n*=2.589)	Quintile 2 (*n*=2,604)	Quintile 3 (*n*=2,647)	Quintile 4 (*n*=2,168)	Quintile 5 (*n*=2,160)
Median score (range)	29 (33-45)	48 (46-49)	51 (50-53)	55 (54-57)	61 (58-77)
Female, %†	46.9	53.7	57.5	58.4	61.0
Black, %†	41.2	30.3	25.2	20.5	15.7
Age, years†	53.1 (5.7)	53.6 (5.7)	53.7 (5.7)	54.3 (5.7)	54.7 (5.7)
High school graduate, %†	67.7	74.1	80.0	81.3	86.6
BMI category†					
Normal weight (<25 kg/m^2)	17.9	19.7	21.6	19.4	21.8
Overweight (25-<30 kg/m^2)	21.6	21.5	21.9	18.1	16.8
Obese (≥30 kg/m^2)	26.3	24.1	21.8	14.8	13.1
Current smoker, %†	28.9	27.8	24.2	22.7	22.0
Physical activity index†	2.3 (0.7)	2.4 (0.8)	2.4 (0.8)	2.5 (0.8)	2.6 (0.8)
Alcohol, g/wk	39.9 (90.6)	43.5 (96.8)	42.9 (92.2)	46.7 (103.6)	47.2 (100.1)
Fasting glucose, mg/dL†	110.3 (42.2)	107.7 (36.9)	107.4 (38.0)	106.9 (39.9)	103.6 (30.7)
Diabetes, %†	12.1	10.9	9.4	10.0	7.7
Hypertension, %†	35.9	34.6	30.7	30.1	26.3
Lipid-lowering medication, %†	1.2	1.9	2.3	3.0	3.5
eGFR, mL/min/1.73 m†	104.7 (16.5)	103.8 (15.5)	103.1 (15.0)	102.2 (14.6)	101.9 (12.9)
Food and Nutrient Intake Per Day					
Healthy plant foods†‡	4.5 (2.4)	5.8 (2.3)	7.0 (2.4)	8.1 (2.5)	10.1 (2.9)
Less healthy plant foods†‡	5.7 (2.8)	5.0 (2.4)	4.9 (2.4)	4.7 (2.3)	4.5 (2.1)
Animal foods†‡	4.8 (2.4)	4.3 (2.0)	4.3 (2.0)	4.2 (1.9)	4.2 (1.8)
Fruit and vegetables†‡	2.0 (1.4)	2.5 (1.3)	3.1 (1.5)	3.7 (1.7)	4.8 (2.0)
Red and processed meat†‡	1.4 (0.9)	1.1 (0.7)	1.1 (0.7)	1.0 (0.7)	0.9 (0.7)
Dairy†‡	1.4 (1.1)	1.5 (1.1)	1.6 (1.1)	1.7 (1.2)	1.9 (1.3)
Fish or seafood†‡	0.3 (0.4)	0.3 (0.2)	0.3 (0.3)	0.3 (0.3)	0.4 (0.3)
Margarine†‡	0.9 (0.8)	1.0 (0.8)	1.0 (0.9)	1.1 (1.0)	1.2 (1.0)
Total energy, kcal†	1557 (574)	1533 (551)	1604 (564)	1671 (546)	1790 (484)
Total protein, % of energy†	17.7 (3.6)	18.1 (3.7)	18.2 (3.8)	18.3 (3.8)	18.6 (3.6)
Animal protein, % of energy†	13.9 (3.7)	13.9 (3.8)	13.8 (3.9)	13.6 (3.9)	13.4 (3.9)
Plant protein, % of energy†	3.8 (0.8)	4.2 (0.9)	4.5 (1.0)	4.7 (1.1)	5.2 (1.2)
Carbohydrates, % of energy†	46.5 (7.8)	47.9 (8.3)	49.2 (8.1)	50.7 (8.7)	52.4 (8.5)
Total fat, % of energy †	35.2 (5.3)	33.5 (5.6)	32.3 (5.8)	30.9 (6.1)	29.4 (6.1)
Saturated fat, % of energy†	12.9 (2.4)	12.2 (2.5)	11.7 (2.4)	11.1 (2.6)	10.3 (2.5)
MUFA, % of energy†	13.9 (2.3)	13.1 (2.5)	12.6 (2.6)	11.9 (2.7)	11.3 (2.8)
PUFA, % of energy†	5.1 (1.1)	5.0 (1.2)	4.9 (1.2)	4.8 (1.2)	4.8 (1.3)
Fiber, g/1000 kcal†	8.3 (2.3)	9.8 (2.8)	11.1 (3.2)	12.2 (3.5)	13.8 (3.8)
Cholesterol, mg/1000 kcal†	181.3 (59.5)	164.4 (54.5)	153.2 (47.8)	143.1 (46.5)	130.7 (42.2)
Sodium, mg/1000 kcal†	901.5 (162)	911.9 (177)	920.6 (175)	933.5 (181)	961.4 (187)

Phosphorous, mg/1000 kcal†	631.7 (144)	660.6 (146)	674.8 (141)	692.5 (145)	715.7 (138)
Calcium, mg/1000 kcal†	371.1 (151)	396.7 (158)	409.3 (156)	428.3 (166)	449.1 (163)
Potassium, mg/1000 kcal†	1444 (319)	1601 (338)	1701 (358)	1790 (367)	1889 (343)
Magnesium, mg/1000 kcal†	136.4 (29.7)	152.9 (32.1)	162.8 (34.1)	172.3 (35.7)	183.6 (33.9)
Iron, mg/1000 kcal†	6.7 (1.9)	7.0 (2.1)	7.2 (2.2)	7.4 (2.3)	7.5 (2.1)
Vitamin A, IU/1000 kcal†	4476 (2587)	5397 (3328)	6147 (3785)	6923 (3973)	7909 (4770)
Vitamin C, mg/1000 kcal†	69.6 (37.5)	75.2 (39.7)	79.4 (40.0)	84.7 (42.0)	88.5 (41.3)
Folate, μg/1000 kcal†	133.6 (45.8)	145.4 (49.6)	153.8 (52.4)	162.4 (53.1)	171.3 (50.7)
Vitamin B12, μg/1000 kcal†	4.9 (2.5)	4.8 (2.3)	4.7 (2.2)	4.5 (2.1)	4.1 (1.9)
Zinc, mg/1000 kcal†	6.6 (1.6)	6.7 (1.6)	6.7 (1.5)	6.7 (1.5)	6.6 (1.3)

ARIC, Atherosclerosis Risk in Communities Study; BMI, body mass index; eGFR, estimated glomerular filtration rate; hPDI, healthy plant-based diet index; IU, international units; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

* Values are means (standard deviations) for continuous variables and % for categorical variables.

† Indicates a statistical difference by quintiles of healthy plant-based diet index ($P<0.05$) tested using analysis of variance for continuous variables and χ^2 test for categorical variables.

‡ Food intakes are expressed as servings per day.

Table S2. Selected Baseline Characteristics and Nutritional Characteristics by Quintiles of the Less Healthy Plant-Based Diet Index (uPDI) in the ARIC Study*

Characteristic	Less Healthy Plant-Based Diet Index (n=12,168)				
	Quintile 1: (*n*=2,470)	Quintile 2: (*n*=2,698)	Quintile 3: (*n*=2,217)	Quintile 4: (*n*=2,824)	Quintile 5: (*n*=1,959)
Median score (range)	43 (27-45)	48 (43-49)	51 (50-52)	55 (53-57)	59 (58-76)
Female, %†	61.6	60.5	55.1	52.8	43.4
Black, %†	23.7	26.7	28.2	28.9	29.2
Age, years†	54.4 (5.7)	54.2 (5.7)	53.7 (5.8)	53.6 (5.7)	53.1 (5.6)
High school graduate, %	81.5	79.4	77.7	75.8	71.9
BMI category					
Normal weight (<25 kg/m^2)	19.4	21.4	18.7	23.6	16.9
Overweight (25-<30 kg/m^2)	20.3	22.6	18.2	23.1	15.8
Obese (≥30 kg/m^2)	21.0	22.5	17.7	22.9	15.9
Current smoker, %	25.8	23.5	25.3	25.1	27.7
Physical activity index†	2.5 (0.8)	2.5 (0.8)	2.4 (0.8)	2.4 (0.8)	2.3 (0.8)
Alcohol, g/wk†	39.6 (78.9)	38.8 (80.2)	39.7 (80.7)	47.9 (107.5)	54.8 (129.1)
Fasting glucose, mg/dL†	110.4 (44.9)	108.2 (39.3)	107.4 (39.5)	106.2 (34.7)	104.0 (27.7)
Diabetes, %†	12.5	11.9	10.1	8.9	6.5
Hypertension, %†	29.5	31.6	32.0	32.7	33.4
Lipid-lowering medication, %	2.3	2.8	2.4	2.2	1.6
eGFR, mL/min/1.73 m^2	102.9 (14.8)	103.5 (14.6)	103.4 (15.3)	103.1 (15.4)	103.1 (15.2)
Food and Nutrient Intake Per Day					
Healthy plant foods†‡	9.2 (3.1)	7.5 (2.9)	6.7 (2.7)	5.9 (2.7)	5.2 (2.6)
Less healthy plant foods†‡	3.7 (2.0)	4.2 (1.8)	4.8 (2.0)	5.5 (2.2)	7.4 (2.7)
Animal foods†‡	5.1 (2.4)	4.4 (2.0)	4.1 (1.9)	4.0 (1.8)	4.1 (1.9)
Fruit and vegetables†‡	4.2 (2.0)	3.4 (1.9)	3.0 (1.7)	2.6 (1.5)	2.3 (1.4)
Red and processed meat†‡	1.1 (0.8)	1.1 (0.8)	1.0 (0.8)	1.1 (0.7)	1.2 (0.7)
Dairy†‡	1.9 (1.2)	1.6 (1.1)	1.5 (1.1)	1.5 (1.2)	1.5 (1.2)
Fish or seafood†‡	0.3 (0.4)	0.3 (0.3)	0.3 (0.3)	0.2 (0.3)	0.2 (0.2)
Margarine†‡	1.1 (0.9)	1.0 (0.8)	1.0 (0.9)	1.0 (0.9)	1.1 (1.0)
Total energy, kcal†	1629 (520)	1526 (506)	1541 (537)	1602 (553)	1869 (603)
Total protein, % of energy†	20.6 (3.4)	19.3 (3.2)	18.2 (3.2)	17.1 (3.2)	15.0 (3.1)
Animal protein, % of energy†	15.9 (3.7)	14.8 (3.5)	13.8 (3.5)	12.8 (3.4)	11.0 (3.1)
Plant protein, % of energy†	3.6 (0.8)	4.2 (0.9)	4.6 (0.9)	4.9 (1.0)	5.3 (1.1)
Carbohydrates, % of energy†	46.9 (7.7)	48.2 (8.4)	49.1 (8.4)	49.8 (8.3)	52.5 (8.8)
Total fat, % of energy†	32.6 (5.9)	32.5 (6.2)	32.5 (6.1)	32.5 (6.0)	31.9 (6.2)
Saturated fat, % of energy†	11.8 (2.6)	11.8 (2.7)	11.7 (2.6)	11.7 (2.6)	11.6 (2.6)
MUFA, % of energy†	12.5 (2.7)	12.6 (2.8)	12.7 (2.7)	12.8 (2.7)	12.6 (2.7)
PUFA, % of energy†	5.0 (1.1)	4.9 (1.2)	5.0 (1.2)	4.9 (1.2)	4.8 (1.3)
Fiber, g/1000 kcal†	12.8 (3.6)	11.8 (3.7)	11.0 (3.5)	9.9 (3.1)	8.6 (2.7)
Cholesterol, mg/1000 kcal†	176.9 (54.5)	165.4 (53.9)	155.8 (53.5)	146.7 (49.6)	130.5 (44.4)
Sodium, mg/1000 kcal†	988.6 (170)	952.0 (173)	932.9 (169)	894.7 (170)	836.9 (167)

Phosphorous, mg/1000 kca†	754.8 (123)	712.6 (129)	679.6 (135)	636.3 (135)	559.9 (132)
Calcium, mg/1000 kcal†	404.7 (183)	410.0 (169)	413.2 (155)	418.4 (151)	398.8 (133)
Potassium, mg/1000 kcal†	1903 (336)	1794 (340)	1699 (338)	1554 (324)	1358 (304)
Magnesium, mg/1000 kcal†	183.6 (34.4)	170.8 (33.3)	162.2 (32.8)	149.2 (30.9)	130.6 (29.6)
Iron, mg/1000 kcal†	7.6 (2.0)	7.5 (2.1)	7.2 (2.2)	6.9 (2.0)	6.3 (1.9)
Vitamin A, IU/1000 kcal†	7925 (4450)	6875 (4049)	6050 (3743)	5194 (3076)	3919 (2388)
Vitamin C, mg/1000 kcal†	81.0 (34.5)	81.0 (38.1)	81.1 (42.3)	76.8 (42.0)	73.9 (45.8)
Folate, µg/1000 kcal†	167.2 (49.8)	161.0 (50.0)	156.8 (53.0)	144.5 (50.1)	127.1 (47.2)
Vitamin B12, µg/1000 kcal†	5.2 (2.3)	5.0 (2.4)	4.6 (2.3)	4.4 (2.1)	3.7 (1.8)
Zinc, mg/1000 kcal†	7.1 (1.3)	6.9 (1.4)	6.7 (1.5)	6.4 (1.5)	5.9 (1.4)

ARIC, Atherosclerosis Risk in Communities Study; BMI, body mass index; eGFR, estimated glomerular filtration rate; IU, international units; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; uPDI, less healthy (unhealthy) plant-based diet index.

* Values are means (standard deviations) for continuous variables and % for categorical variables.

† Indicates a statistical difference by quintiles of less healthy plant-based diet index (P <0.05) tested using analysis of variance for continuous variables and χ^2 test for categorical variables.

‡ Food intakes are expressed as servings per day.

Table S3. Incidence Rates and Minimally Adjusted* Hazard Ratios and 95% Confidence Intervals for Incident Cardiovascular Disease, Cardiovascular Disease Mortality, and All-Cause Mortality According to Quintiles of All Four Plant-Based Diet Indices

		Incident Cardiovascular Disease		Cardiovascular Disease Mortality		All-Cause Mortality	
		IR per 100,000 PY	HR (95% CI)	IR per 100,000 PY	HR (95% CI)	IR per 100,000 PY	HR (95% CI)
Overall Plant-Based Diet Index (PDI)	Q1	4.5 (4.3, 4.9)	1 [Ref]	2.2 (1.9, 2.3)	1 [Ref]	6.5 (6.2, 6.8)	1 [Ref]
	Q2	4.1 (3.8, 4.4)	0.96 (0.87, 1.05)	1.6 (1.4, 1.8)	0.84 (0.73, 0.96)	5.3 (4.9, 5.6)	0.86 (0.79, 0.93)
	Q3	3.9 (3.7, 4.2)	0.91 (0.84, 1.00)	1.4 (1.3, 1.6)	0.77 (0.68, 0.88)	4.8 (4.6, 5.1)	0.78 (0.73, 0.84)
	Q4	3.4 (3.2, 3.7)	0.79 (0.72, 0.88)	1.3 (1.1, 1.4)	0.66 (0.56, 0.77)	4.6 (4.3, 4.9)	0.72 (0.66, 0.78)
	Q5	3.3 (3.1, 3.5)	0.75 (0.68, 0.83)	1.1 (0.9, 1.2)	0.60 (0.52, 0.71)	4.1 (3.9, 4.4)	0.65 (0.60, 0.71)
	P trend		<0.001		<0.001		<0.001
Healthy Plant-Based Diet Index (hPDI)	Q1	4.9 (4.6, 5.2)	1 [Ref]	1.8 (1.6, 1.9)	1 [Ref]	5.4 (5.1, 5.7)	1 [Ref]
	Q2	4.7 (4.4, 4.9)	0.98 (0.89, 1.07)	1.5 (1.4, 1.7)	0.94 (0.81, 1.08)	5.1 (4.8, 5.4)	0.98 (0.90, 1.06)
	Q3	4.2 (3.9, 4.5)	0.91 (0.83,1.00)	1.4 (1.2, 1.5)	0.87 (0.75, 1.01)	4.8 (4.5, 5.1)	0.90 (0.83, 0.98)
	Q4	4.3 (3.9, 4.6)	0.90 (0.82, 1.00)	1.2 (1.1, 1.4)	0.75 (0.63, 0.88)	4.7 (4.4, 5.0)	0.83 (0.76, 0.91)
	Q5	4.2 (3.9, 4.5)	0.80 (0.73, 0.89)	1.1 (1.0, 1.3)	0.70 (0.59, 0.83)	4.6 (4.4, 4.9)	0.79 (0.72, 0.86)
	P trend		<0.001		<0.001		<0.001
Less Healthy (unhealthy) Plant-Based Diet Index (uPDI)	Q1	4.0 (3.8, 4.3)	1 [Ref]	1.5 (1.4, 1.7)	1 [Ref]	5.3 (5.0, 5.6)	1 [Ref]
	Q2	3.9 (3.7, 4.2)	0.98 (0.89, 1.07)	1.5 (1.4, 1.7)	0.97 (0.84, 1.11)	5.1 (4.9, 5.4)	1.02 (0.94, 1.10)
	Q3	3.8 (3.6, 4.1)	0.97 (0.88, 1.07)	1.5 (1.4, 1.7)	0.93 (0.80, 1.09)	4.9 (4.6, 5.3)	0.95 (0.88, 1.04)
	Q4	3.7 (3.5, 4.0)	0.96 (0.87, 1.05)	1.4 (1.3, 1.6)	0.87 (0.75, 1.01)	4.7 (4.4, 5.0)	0.99 (0.92, 1.08)
	Q5	3.9 (3.7, 4.2)	0.98 (0.89, 1.08)	1.5 (1.3, 1.7)	1.00 (0.86, 1.16)	4.6 (4.3, 4.9)	1.00 (0.92, 1.08)
	P trend		0.53		0.75		0.95
Provegetarian Diet Index	Q1	4.4 (4.1, 4.6)	1 [Ref]	1.8 (1.7, 2.0)	1 [Ref]	5.8 (5.6, 6.1)	1 [Ref]
	Q2	4.0 (3.8, 4.3)	0.92 (0.84, 1.00)	1.6 (1.5, 1.8)	0.88 (0.77, 1.00)	5.2 (5.0, 5.5)	0.88 (0.82, 0.94)
	Q3	3.6 (3.3, 3.8)	0.82 (0.74, 0.90)	1.3 (1.2, 1.5)	0.75 (0.64, 0.87)	4.9 (4.6, 5.3)	0.84 (0.78, 0.91)
	Q4	3.7 (3.5, 4.0)	0.85 (0.77, 0.93)	1.4 (1.3, 1.6)	0.78 (0.68, 0.90)	4.7 (4.4, 5.0)	0.77 (0.71, 0.83)
	Q5	3.5 (3.3, 3.8)	0.75 (0.68, 0.82)	1.2 (1.0, 1.3)	0.60 (0.52, 0.70)	4.6 (4.3, 4.9)	0.70 (0.65, 0.76)
	P trend		<0.001		<0.001		<0.001

CI, confidence intervals; HR, hazard ratios; IR, incidence rate; PY, person-years; Ref., reference

* Adjusted for age, sex, race-center, total energy intake.

Table S4. Hazard Ratios and 95% Confidence Intervals for Incident Cardiovascular Disease, Cardiovascular Disease Mortality and All-Cause Mortality According to Quintiles of Plant-Based Diet Indices*

		Hazard Ratios (95% Confidence Intervals)		
		Incident Cardiovascular Disease	Cardiovascular Disease Mortality	All-Cause Mortality
Number of events		4,381	1,565	5,436
Overall Plant-Based Diet Index (PDI)	Q1	1 [Ref]	1 [Ref]	1 [Ref]
	Q2	0.99 (0.90, 1.09)	0.86 (0.74, 0.99)	0.89 (0.83, 0.97)
	Q3	0.93 (0.85, 1.02)	0.80 (0.70, 0.92)	0.82 (0.76, 0.89)
	Q4	0.84 (0.76, 0.94)	0.73 (0.62, 0.86)	0.82 (0.75, 0.89)
	Q5	0.84 (0.76, 0.94)	0.69 (0.58, 0.81)	0.76 (0.69, 0.83)
	P trend	<0.001	<0.001	<0.001
Healthy Plant-Based Diet Index (hPDI)	Q1	1 [Ref]	1 [Ref]	1 [Ref]
	Q2	0.99 (0.90, 1.08)	0.96 (0.82, 1.11)	0.99 (0.91, 1.07)
	Q3	1.00 (0.91, 1.10)	0.98 (0.84, 1.15)	0.99 (0.91, 1.08)
	Q4	1.01 (0.91, 1.11)	0.84 (0.71, 1.00)	0.93 (0.85, 1.02)
	Q5	0.95 (0.86, 1.06)	0.84 (0.71, 1.01)	0.91 (0.83, 1.00)
	P trend	0.56	0.03	0.03
Less Healthy (unhealthy) Plant-Based Diet Index (uPDI)	Q1	1 [Ref]	1 [Ref]	1 [Ref]
	Q2	0.95 (0.86, 1.04)	0.99 (0.86, 1.14)	1.04 (0.96, 1.12)
	Q3	0.99 (0.90, 1.10)	0.94 (0.81, 1.10)	0.97 (0.89, 1.05)
	Q4	1.02 (0.93, 1.11)	0.91 (0.78, 1.06)	1.01 (0.93, 1.10)
	Q5	0.93 (0.83, 1.03)	1.05 (0.90, 1.22)	1.02 (0.94, 1.11)
	P trend	0.48	0.94	0.67
Provegetarian Diet Index	Q1	1 [Ref]	1 [Ref]	1 [Ref]
	Q2	0.95 (0.87, 1.04)	0.90 (0.78, 1.03)	0.92 (0.85, 0.99)
	Q3	0.82 (0.74, 0.91)	0.76 (0.65, 0.89)	0.89 (0.82, 0.97)
	Q4	0.87 (0.79, 0.96)	0.82 (0.71, 0.95)	0.84 (0.77, 0.91)
	Q5	0.85 (0.77, 0.94)	0.68 (0.58, 0.80)	0.82 (0.76, 0.89)
	P trend	<0.001	<0.001	<0.001

* Adjusted for age, sex, race-center, total energy intake, education, smoking status, physical activity, alcohol consumption, margarine consumption, baseline total cholesterol, lipid medication use, baseline kidney function (two linear spline terms with 1 knot at 90ml/min/1.73m^2), hypertension, diabetes, and baseline body mass index.

Table S5. Adjusted Hazard Ratios and 95% Confidence Intervals for Cardiovascular Disease Outcomes for Highest versus Lowest Quintiles of Score Components of the Overall Plant-Based Diet Index and Provegetarian Diet Index [*]

	Hazard Ratios (95% Confidence Intervals)					
	Incident Cardiovascular Disease	*P* trend	Cardiovascular Disease Mortality	*P* trend	All-Cause Mortality	*P* trend
Score Components of Overall Plant-Based Diet Index[†]						
Healthy plant food	1.01 (0.91, 1.13)	0.75	0.96 (0.81, 1.14)	0.38	0.90 (0.82, 0.99)	0.09
Less healthy plant food	1.00 (0.90, 1.11)	0.85	1.08 (0.91, 1.29)	0.42	0.97 (0.88, 1.06)	0.30
Animal food	1.14 (1.04, 1.27)	<0.001	1.30 (1.10, 1.54)	<0.001	1.12 (1.02, 1.23)	0.001
Score Components of Provegetarian Diet Index[‡]						
Plant food (selected)	0.95 (0.86, 1.05)	0.05	0.85 (0.71, 1.00)	0.009	0.87 (0.79, 0.96)	<0.001
Animal food (selected)	1.15 (1.04, 1.26)	<0.001	1.27 (1.08, 1.49)	0.002	1.12 (1.03, 1.23)	0.007

[*] Adjusted for age, sex, race-center, and total energy intake, education, smoking status, physical activity, alcohol consumption, margarine consumption, baseline total cholesterol, lipid-lowering medication use, kidney function (two linear spline terms with one knot at 90 mL/min/1.73 m^2), hypertension, diabetes, and body mass index.

[†] Healthy plant food intakes were aggregated consumption of whole grains, fruits, vegetables, nuts, legumes, and coffee and tea. Less healthy plant food intakes were aggregated consumption of fruit juices, refined grains, potatoes, sugar sweetened beverages, and sweets and desserts. Animal food intakes were aggregated consumption of animal fat, dairy, eggs, fish or seafood, meat, and miscellaneous animal foods.

[‡] Plant food (selected) intakes were aggregated consumption of grains (whole and refined), fruits, vegetables, nuts, legumes, and potatoes. Animal food (selected) intakes were aggregated consumption of animal fat, dairy, eggs, fish or seafood, and meat.

Table S6. Per Serving Increase in Individual Food Groups within the Overall Plant-Based Diet Index and Provegetarian Diet Index and Risk of Incident Cardiovascular Disease, Cardiovascular Disease Mortality, and All-Cause Mortality*

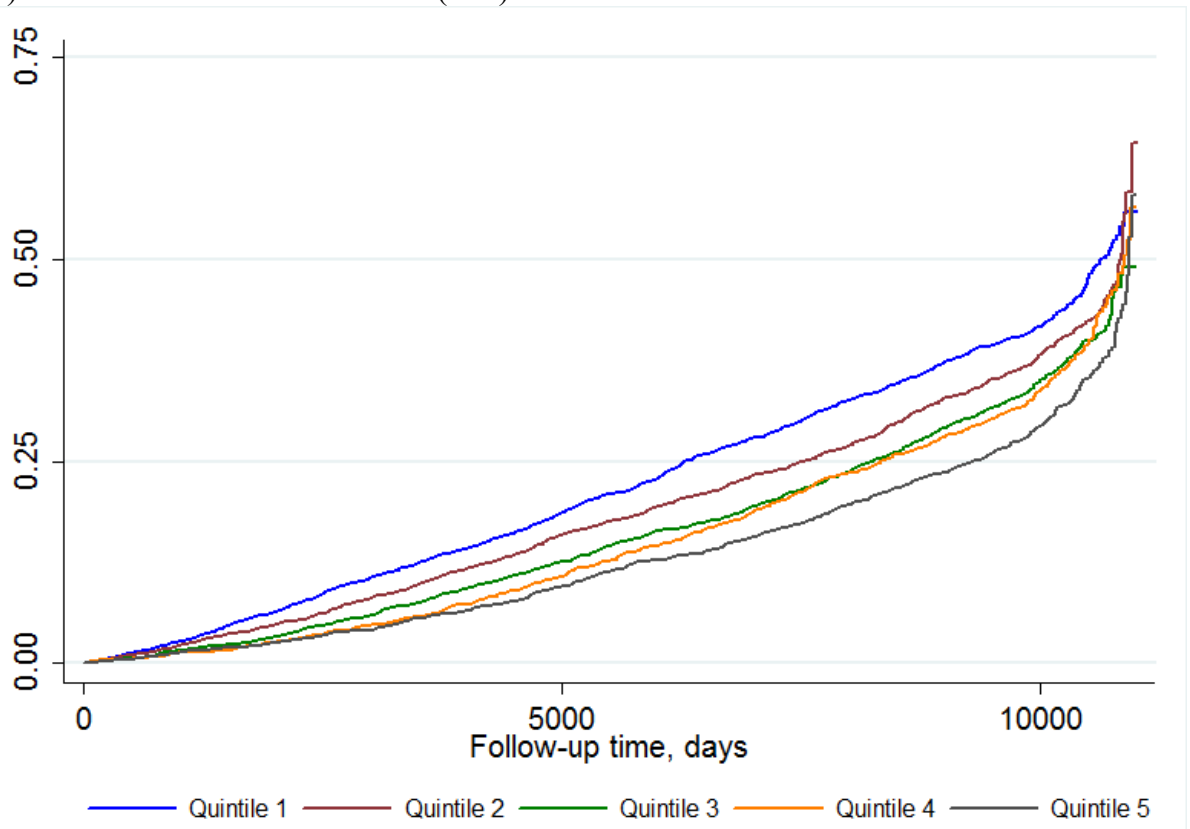
	Incident Cardiovascular Disease	Cardiovascular Disease Mortality	All-Cause Mortality
Overall Plant-Based Diet Index			
Healthy Plant Foods			
Whole grains	0.95 (0.91, 0.99)	0.90 (0.83, 0.97)	0.95 (0.91, 0.98)
Fruits	1.00 (0.97, 1.03)	0.98 (0.92, 1.03)	0.98 (0.95, 1.01)
Vegetables	1.00 (0.95, 1.03)	0.98 (0.91, 1.05)	0.99 (0.94, 1.02)
Nuts	1.02 (0.94, 1.09)	1.00 (0.88, 1.13)	0.99 (0.93, 1.05)
Legumes	0.96 (0.88, 1.04)	1.01 (0.89, 1.15)	0.99 (0.92, 1.06)
Coffee and tea	1.03 (1.01, 1.04)	1.03 (0.99, 1.06)	1.01 (0.99, 1.02)
Less Healthy Plant Foods			
Refined grains	0.99 (0.95, 1.01)	1.02 (0.97, 1.07)	1.00 (0.97, 1.02)
Potatoes	0.86 (0.76, 0.97)	0.87 (0.71, 1.06)	0.84 (0.75, 0.93)
Fruit juices	0.99 (0.93, 1.05)	1.04 (0.93, 1.14)	0.97 (0.92, 1.02)
SSBs	1.02 (0.98, 1.05)	1.03 (0.97, 1.09)	1.01 (0.98, 1.04)
Sweets and desserts	0.97 (0.93, 1.00)	0.97 (0.91, 1.03)	0.95 (0.92, 0.98)
Animal Foods			
Animal fat	1.00 (0.94, 1.05)	1.06 (0.96, 1.15)	0.97 (0.92, 1.01)
Dairy	1.02 (0.98, 1.05)	1.05 (0.99, 1.11)	1.03 (0.99, 1.05)
Meat			
Red and processed meat	1.09 (1.03, 1.14)	1.12 (1.02, 1.21)	1.08 (1.02, 1.13)
Poultry	0.91 (0.81, 1.01)	0.87 (0.71, 1.04)	0.86 (0.77, 0.95)
Eggs	1.16 (1.05, 1.26)	1.16 (1.01, 1.33)	1.10 (1.02, 1.19)
Fish or seafood	0.95 (0.84, 1.07)	0.88 (0.71, 1.08)	0.91 (0.81, 1.02)
Miscellaneous animal foods	1.00 (0.91, 1.09)	0.96 (0.82, 1.10)	1.06 (0.97, 1.14)
Provegetarian diet index			
Plant Foods			
Fruits	1.00 (0.96, 1.03)	0.97 (0.92, 1.02)	0.98 (0.95, 1.00)
Vegetables	1.01 (0.96, 1.05)	0.99 (0.92, 1.07)	1.01 (0.96, 1.05)
Nuts	1.02 (0.94, 1.09)	0.99 (0.87, 1.12)	0.99 (0.92, 1.05)
Legumes	0.95 (0.88, 1.03)	1.01 (0.88, 1.14)	0.99 (0.91, 1.05)
Grains	0.98 (0.95, 1.00)	0.99 (0.94, 1.03)	0.99 (0.96, 1.01)
Potatoes	0.88 (0.80, 0.96)	0.89 (0.76, 1.03)	0.85 (0.78, 0.92)
Animal Foods			
Animal fat	1.01 (0.95, 1.06)	1.06 (0.96, 1.15)	0.98 (0.93, 1.02)
Dairy	1.02 (0.98, 1.04)	1.05 (0.99, 1.10)	1.03 (0.99, 1.05)
Meat			
Red and processed meat	1.10 (1.04, 1.16)	1.13 (1.03, 1.22)	1.10 (1.05, 1.15)
Poultry	0.92 (0.82, 1.02)	0.87 (0.72, 1.06)	0.87 (0.78, 0.96)
Eggs	1.16 (1.06, 1.26)	1.17 (1.02, 1.34)	1.12 (1.03, 1.21)
Fish or seafood	0.94 (0.83, 1.06)	0.86 (0.69, 1.05)	0.91 (0.80, 1.01)

SSBs, sugar-sweetened beverages.

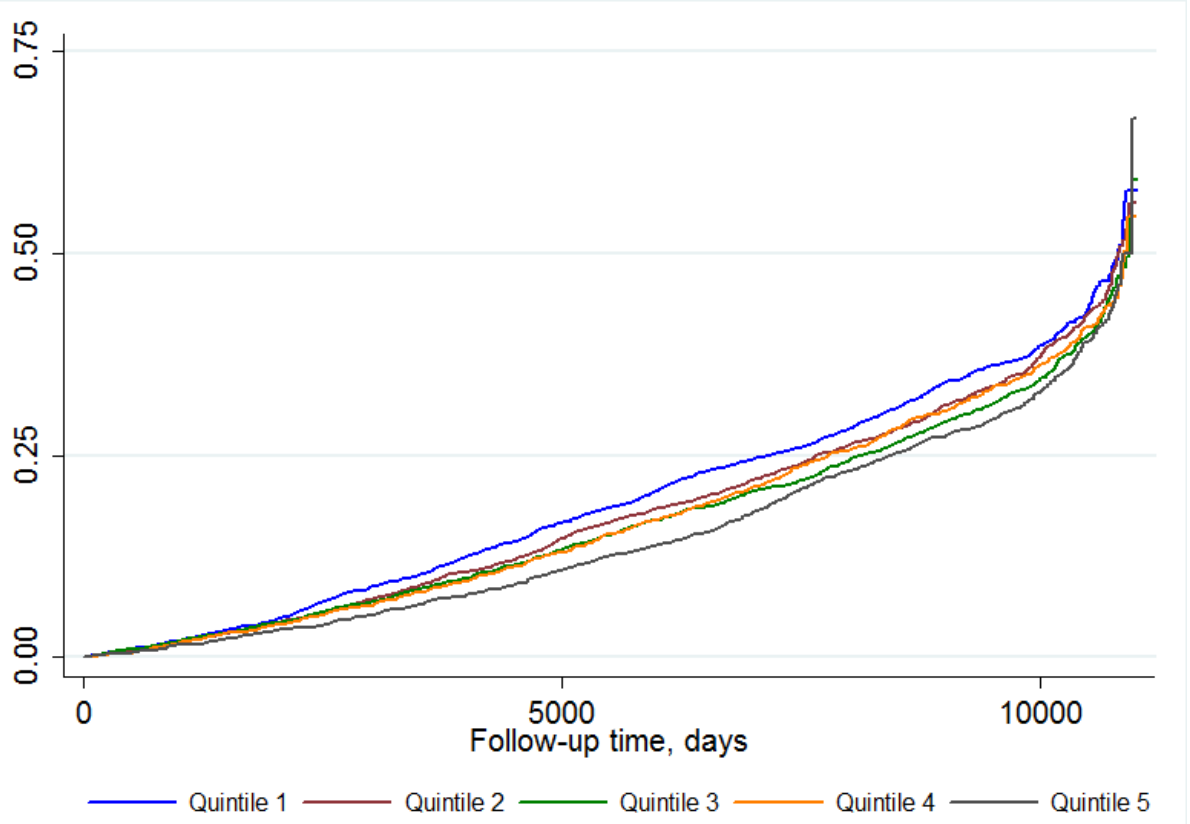
* Adjusted for age, sex, race-center, and total energy intake, education, smoking status, physical activity, alcohol consumption, margarine consumption, baseline total cholesterol, lipid-lowering medication use, kidney function (two linear spline terms with one knot at 90 mL/min/1.73 m^2), hypertension, diabetes, and body mass index.

Figure S1. Cumulative incidence of incident cardiovascular disease mortality according to quintiles of all plant-based diet indices

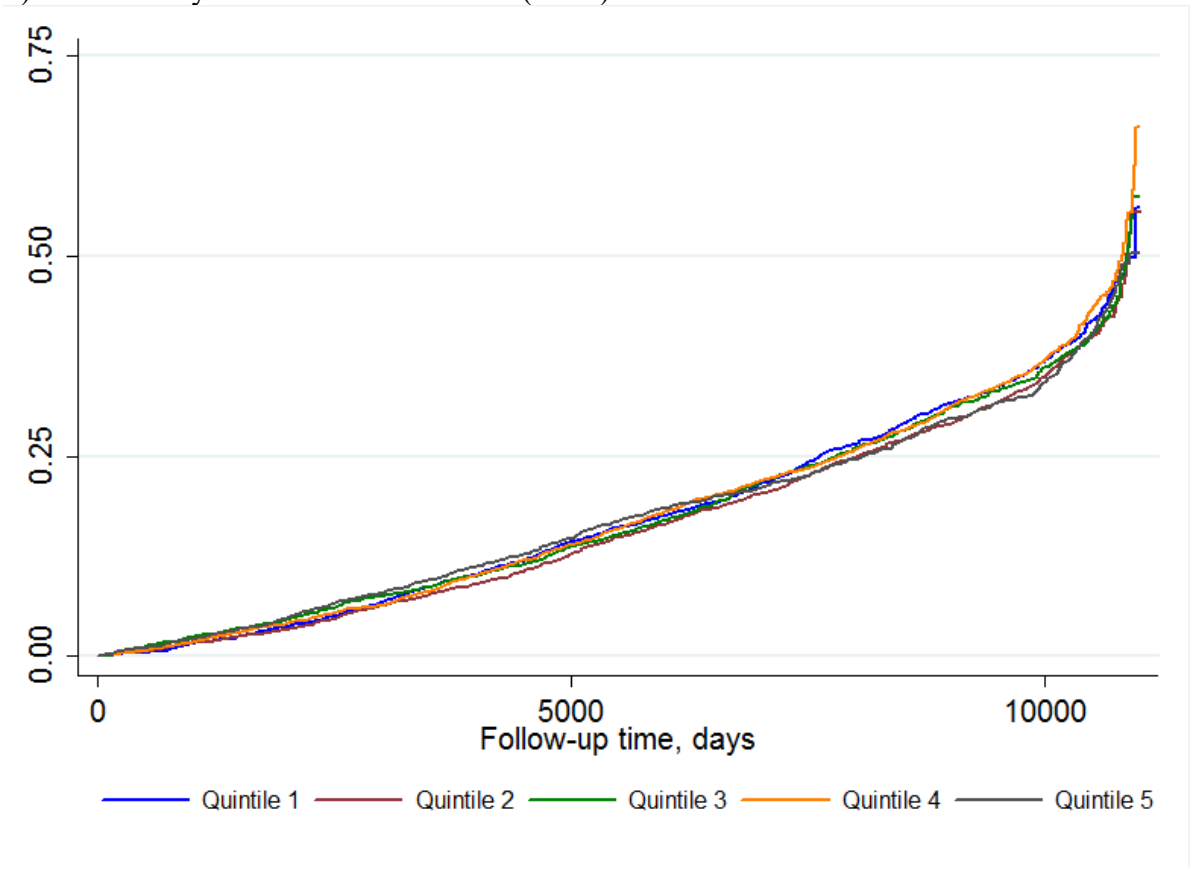
A) Overall Plant-Based Diet Index (PDI)



B) Healthy Plant-Based Diet Index (hPDI)



C) Less Healthy Plant-Based Diet Index (uPDI)



D) Provegetarian diet index

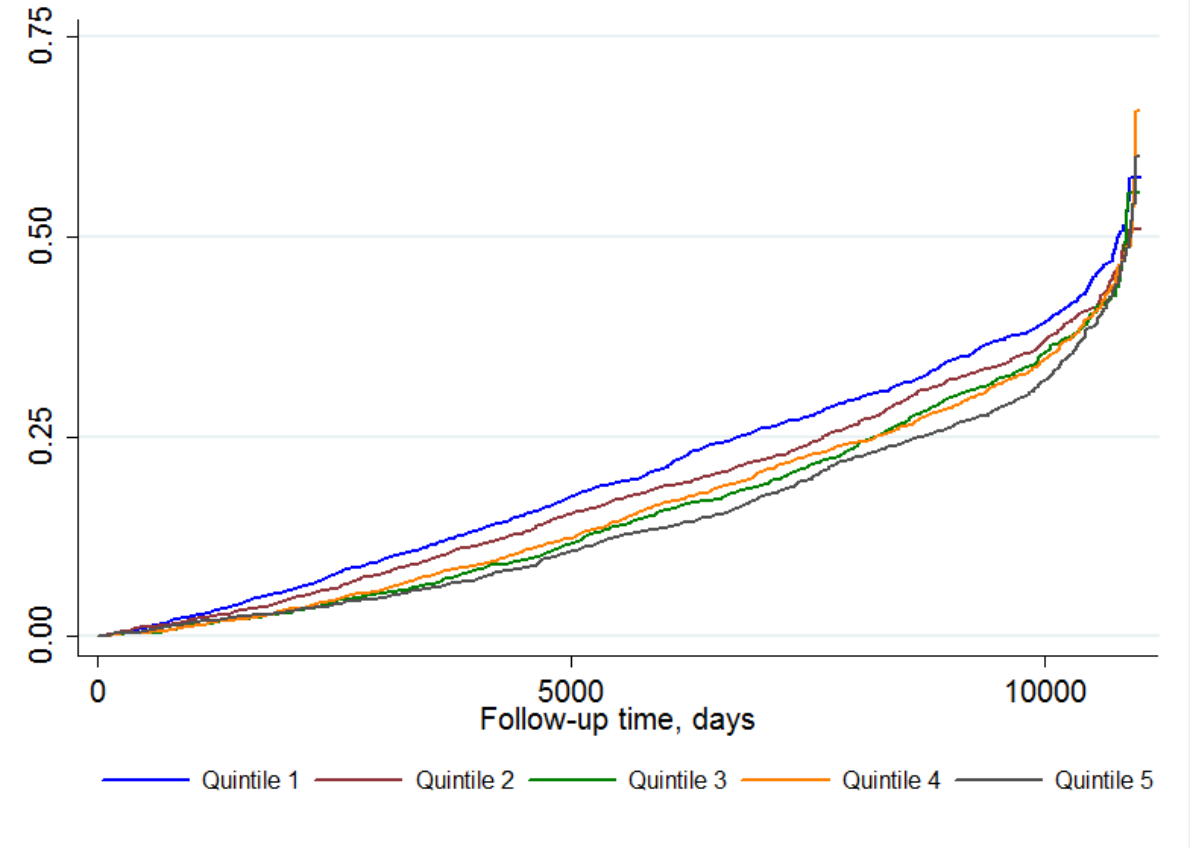
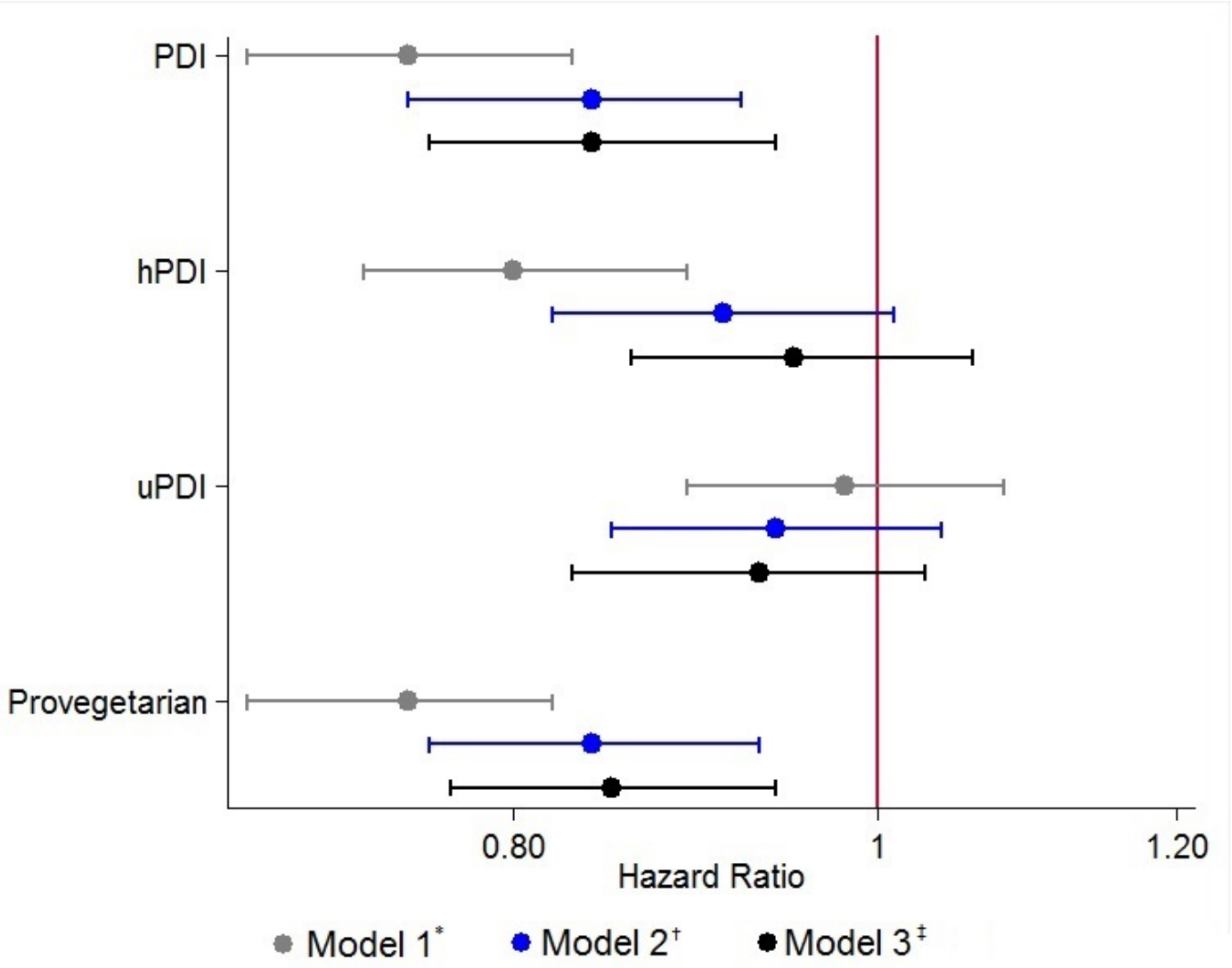


Figure S2. Adjusted hazard ratios and 95% confidence intervals for incident cardiovascular disease comparing those in the highest vs. lowest quintiles of all plant-based diet indices



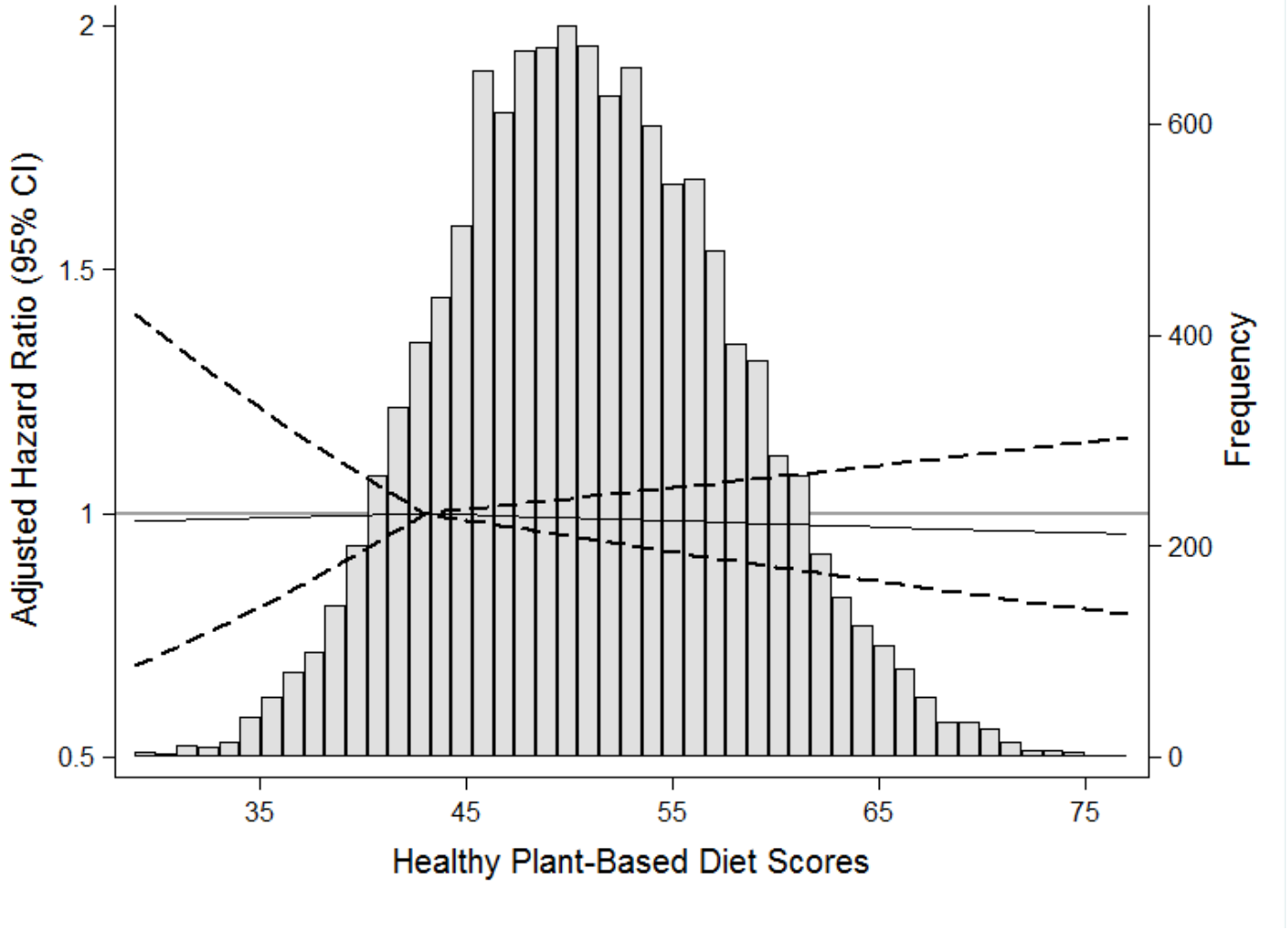
PDI, overall plant-based diet index; hPDI, healthy plant-based diet index; uPDI, less healthy plant-based diet index.

* In model 1, age, sex, race-center, and total energy intake were adjusted.

† In model 2, education, smoking status, physical activity, alcohol consumption, and margarine consumption were additionally adjusted.

‡ In model 3, baseline total cholesterol, lipid medication use, baseline kidney function, hypertension, diabetes, and baseline body mass index were additionally adjusted.

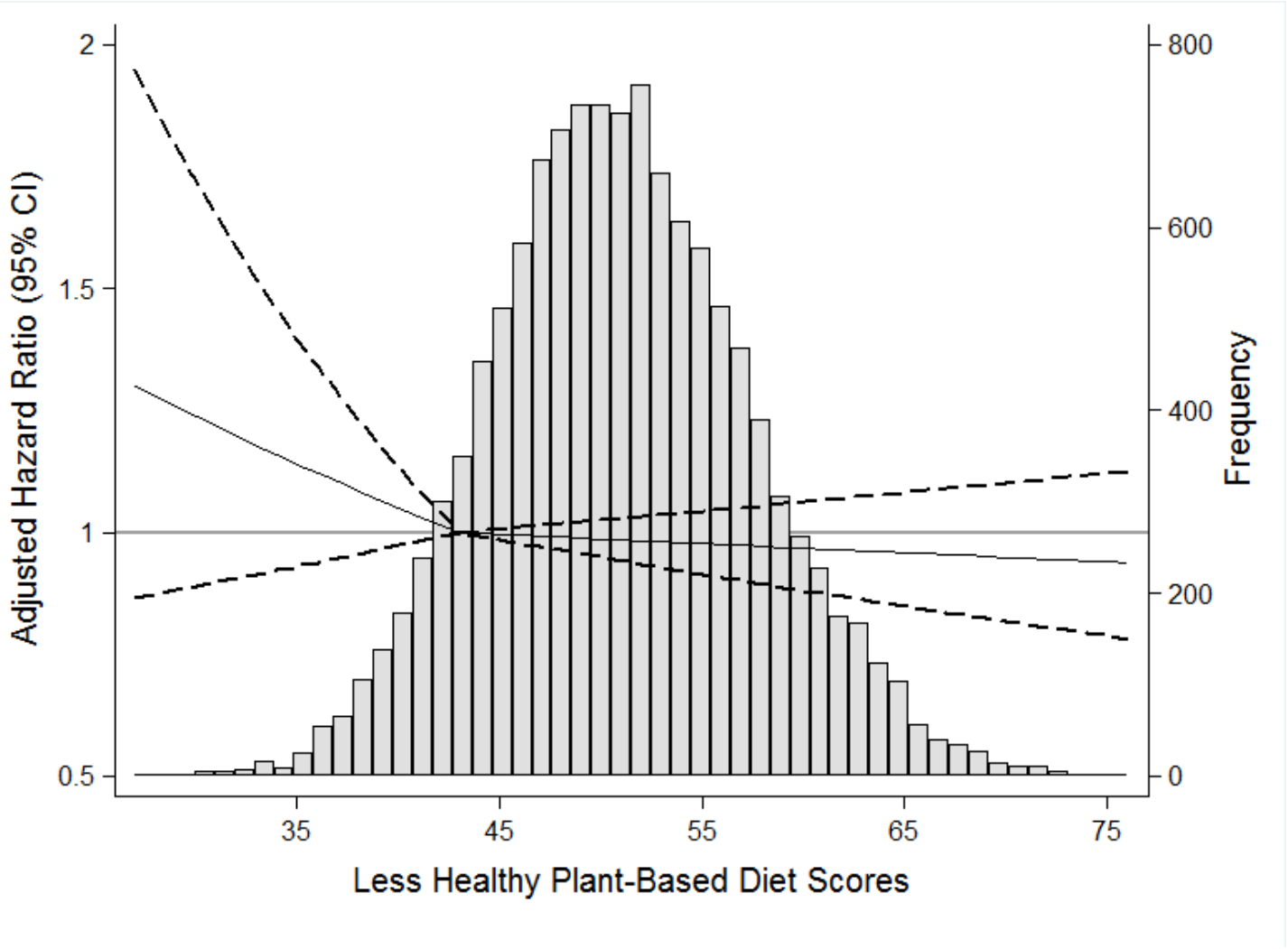
Figure S3. Adjusted hazard ratios* and 95% confidence intervals for incident cardiovascular disease according to the continuous healthy plant-based diet score (hPDI)



The histogram shows the distribution of scores for the healthy plant-based diet index (hPDI) in gray. The solid lines represent the adjusted hazard ratios for incident cardiovascular disease modeled using two linear spline terms with one knot at the 12.5th percentile of the hPDI (score: 43), which was used as the reference point. The dashed lines represent the 95% confidence intervals.

* Adjusted for age, sex, race-center, total energy intake, education, smoking status, physical activity, alcohol consumption, margarine consumption, baseline total cholesterol, lipid medication use, baseline kidney function, hypertension, diabetes, and baseline body mass index.

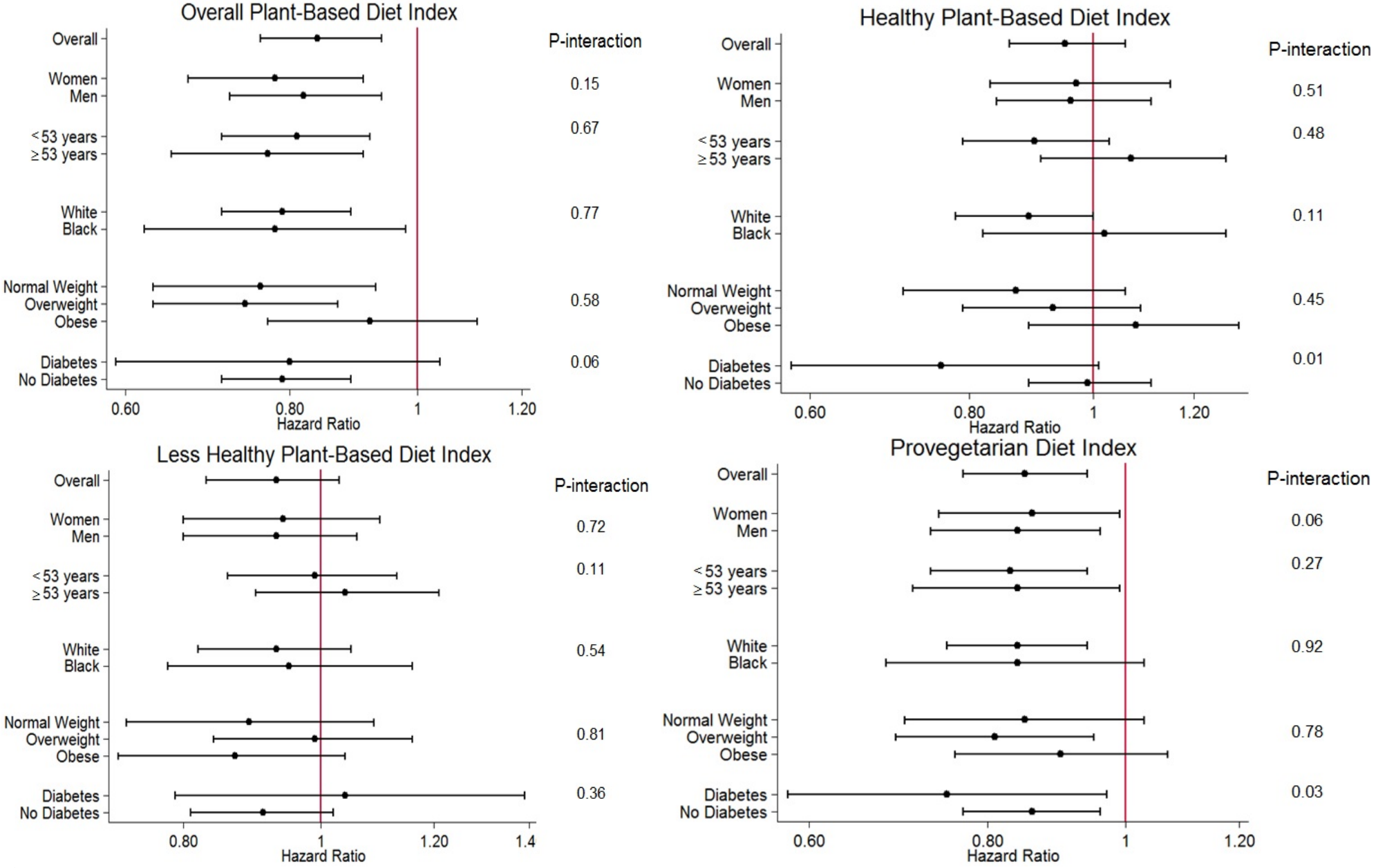
Figure S4. Adjusted hazard ratios* and 95% confidence intervals for incident cardiovascular disease according to the continuous less healthy plant-based diet score (uPDI)



The histogram shows the distribution of scores for the less healthy plant-based diet index (uPDI) in gray. The solid lines represent the adjusted hazard ratios for incident cardiovascular disease modeled using two linear splines terms with one knot at the 12.5th percentile of the uPDI (score: 43), which was used as the reference point. The dashed lines represent the 95% confidence intervals.

* Adjusted for age, sex, race-center, total energy intake, education, smoking status, physical activity, alcohol consumption, margarine consumption, baseline total cholesterol, lipid medication use, baseline kidney function, hypertension, diabetes, and baseline body mass index.

Figure S5. Adjusted hazard ratios* and 95% confidence intervals for incident cardiovascular disease for highest versus lowest quintiles of plant-based diet scores according to sex, age, race, baseline weight status, and baseline diabetes status



* Adjusted for age, sex, race-center, total energy intake, education, smoking status, physical activity, alcohol consumption, margarine consumption, baseline total cholesterol, lipid medication use, baseline kidney function, hypertension, diabetes, and baseline body mass index.