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The Portfolio Diet and Incident Type 2 Diabetes: Findings From the Women's Health Initiative Prospective Cohort Study

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OBJECTIVE

A plant-based dietary pattern, the Portfolio Diet, has been shown to lower LDL cholesterol and other cardiovascular disease risk factors. However, no study has evaluated the association of this diet with incident type 2 diabetes.

RESEARCH DESIGN AND METHODS

This analysis included 145,299 postmenopausal women free of diabetes at baseline in the Women's Health Initiative (WHI) Clinical Trials and Observational Study from 1993 to 2021. Adherence to the diet was assessed with a score based on six components (high in plant protein [soy and pulses], nuts, viscous fiber, plant sterols, and monounsaturated fat and low in saturated fat and cholesterol) determined from a validated food-frequency questionnaire. We used Cox proportional hazards models to estimate hazard ratios (HRs) and 95% CIs of the association of the Portfolio Diet, alongside the Dietary Approaches to Stop Hypertension (DASH) and Mediterranean diets, with incident type 2 diabetes, with adjustment for potential confounders.

RESULTS

Over a mean follow-up of 16.0 years, 13,943 cases of incident type 2 diabetes were identified. In comparisons of the highest with the lowest quintiles of adherence, the HRs for risk of incident type 2 diabetes were 0.77 (95% CI 0.72, 0.82) for the Portfolio Diet, 0.69 (0.64, 0.73) for the DASH diet, and 0.78 (0.74, 0.83) for the Mediterranean diet. These findings were attenuated by 10% after additional adjustment for BMI.

CONCLUSIONS

Greater adherence to the plant-predominant Portfolio, DASH, and Mediterranean diets was prospectively associated with lower risk of type 2 diabetes in postmenopausal women.

Type 2 diabetes continues to be a major burden globally, and a healthy diet plays a key role in the prevention of this chronic disease (1,2). Plant-based diets in particular are thought to be beneficial for the prevention of type 2 diabetes (3); however, findings from meta-analyses have found that the certainty of evidence for plant-based diets and incidence of type 2 diabetes is low, highlighting that more research on this topic is needed (4). The plant-based Portfolio Diet has been associated with lower cardiovascular disease (CVD) risk among U.S. postmenopausal women and lower mortality risk among Hong Kong older adults in two prospective cohort studies (5,6). We recently showed that greater

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adherence to the diet was associated with reductions in several risk factors for diabetes, including markers of glycemic control and adiposity in a population of older adults with metabolic syndrome (7); however, this dietary approach has yet to be assessed in the prevention of type 2 diabetes. Other well-known dietary patterns that are plant predominant and recommended for lowering CVD risk, and may also be beneficial for diabetes prevention, include the Dietary Approaches to Stop Hypertension (DASH) and Mediterranean diets. While conducting a long-term randomized trial with type 2 diabetes as the primary outcome would be preferred, this type of trial is currently not feasible (8). Thus, high-quality and large prospective cohort studies remain the "alloyed gold" standard platform in evaluating the long-term effectiveness of diet for type 2 diabetes prevention. In this study, we examined the association of the Portfolio Diet, alongside the DASH and Mediterranean diets, with incident type 2 diabetes among postmenopausal women from the Women's Health Initiative (WHI).

RESEARCH DESIGN AND METHODS

Study Population and Design

Between 1993 and 1998, postmenopausal women aged 50–79 years were recruited into the WHI clinical trials (CT) or a concomitant observational study (OS) if not assigned to a CT (n = 161,808). The design and methods of the WHI have previously been published (9–11), and recruitment and baseline data collection were previously reported (10). Written informed consent was obtained from all participants, and procedures were approved by institutional review boards at all participating institutions. We excluded participants who had a diagnosis of type 2 diabetes at baseline (n = 9,179), missing information on diet or lifestyle covariates (n = 2,732), or implausible caloric intake ($<$600 kcal or $>$5,000 kcal/day) (n = 4,598). Details regarding the implausible caloric intake can be found in the WHI protocol (12). For baseline diabetes status, participants were asked whether a physician had ever told them they had "sugar diabetes or high blood sugar" when they were not pregnant and about treatment with insulin or oral diabetes medications. Baseline type 2 diabetes was defined as a confirmatory answer to the above question or reported use of medication to treat diabetes. This current analysis includes follow-up through 6 March 2021 and 145,299 women. The WHI data are accessible to researchers, and requests to access the data set may be sent to the WHI Publications and Presentations Committee.

Dietary Assessment

The primary exposure was diet as measured according to a Portfolio Diet score, previously developed and validated using a modified Willett food-frequency questionnaire (FFQ) against LDL cholesterol and 7-day diet records (13). The foods and nutrients included in this score were based on self-reported intake at enrollment and again at year 3 for the OS participants with use of the FFQ developed and validated for the WHI (14,15). We used an average score for those who completed the FFQ at baseline and year 3. Food items on the WHI FFQ were categorized into the six components of the diet (plant protein, nuts, viscous fiber, plant sterols, monounsaturated fatty acids (MUFAs), and high–saturated fat/dietary cholesterol sources). Intake was assessed as servings per day reported from the FFQ of targeted foods in all components except plant sterols, for which all FFQ food items were used to derive total intake (milligrams per day). For the six components, each was scored from 1 (least adherent) to 5 (most adherent) according to participant's quintile of intake, resulting in a score range between 6 and 30. For the DASH and Mediterranean diets, we used diet scores widely applied in the epidemiology literature (16–18). The DASH score included eight components, with total scores ranging from 8 to 40. The Alternate Mediterranean Diet (aMED) score included nine components and total scores ranging from 0 to 9. Higher scores indicate higher adherence for each dietary pattern. The development of the Portfolio Diet score in the WHI has previously been described (5), and additional information on the DASH and aMED scores is included in Supplementary Material.

Ascertainment of Type 2 Diabetes

Only incident cases of type 2 diabetes were ascertained, defined as a self-report of physician-diagnosed diabetes treated with oral medication or insulin (19,20), determined at each semiannual (WHI CT) or annual (WHI OS) contact. Validation studies of the self-reported diabetes with use of both medical records and biomarkers indicated high accuracy and reliability (21,22). Time to diabetes was defined as the number of days from enrollment to the return of the questionnaire in which diabetes was first reported.

Covariates

Covariates that were included in our models were based on information on the participants' lifestyle and risk factors for diabetes assessed at baseline, including age, region in the U.S, self-identified race and ethnicity, alcohol intake, physical activity, energy intake, hysterectomy history, BMI, hormone therapy (HT) use, personal history of hypertension and high cholesterol, family history of diabetes, smoking status, education, marital status, and CT/study arm. Detailed

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descriptions of the validity and reproducibility of baseline measurements have previously been published (11).

Statistical Analysis

Baseline characteristics were described by quintile of each dietary pattern score with means and SDs for continuous variables and frequencies with percentages for categorical variables. Participants were categorized according to quintiles of the dietary scores, with the lowest quintile serving as the reference group. For our main analysis, we used Cox proportional hazards models to estimate hazard ratios (HRs) and 95% CIs for the association between the three dietary pattern score quintiles and incident type 2 diabetes. Three multivariable models were used. Covariates commonly examined in studies of dietary pattern indices and type 2 diabetes were included based on our a priori analysis plan. Model 1 included adjustment for age (continuous), region (Northeast, South, Midwest, West), smoking status (never, past, current), and study arm (HT arm, dietary modification [DM] arm, calcium and vitamin D [CaD] arm). Model 2 included model 1 adjustments plus adjustment for self-identified race and ethnicity (White, African American, Hispanic, Asian), education (college or above, below college), marital status (presently married, other), hysterectomy history (yes, no), physical activity (continuous), alcohol intake ($\geq$7 drinks/week, $<$7 drinks/week), energy intake (continuous), hypertension status (yes, no), family history of diabetes (yes, no), postmenopausal hormone use (never, past, current), and cholesterol-lowering medication use (yes, no). Model 3 included model 2 adjustments plus adjustment for BMI (continuous), for examination of the potential role of obesity in the diet and type 2 diabetes relationship. We verified the proportional hazards model assumptions using Schoenfeld residuals method, and no violations of the assumption were found. Tests for linear trend were conducted through assigning the median value to each quintile. We further examined associations with incident type 2 diabetes per 1 SD increase in each score to facilitate comparisons across the scores, as they all have different score ranges. We used restricted cubic spline plots with four knots to explore the shape of the association between the dietary scores and incident type 2 diabetes. We also analyzed the Spearman rank correlation coefficients between the three dietary patterns.

We conducted several sensitivity and subgroup analyses to test the robustness of our Portfolio Diet findings, as this is the first time the Portfolio Diet score has been assessed with type 2 diabetes incidence. The sensitivity analyses include the following: *1*) restricting the data to the OS participants only, *2*) restricting analyses to the baseline diet score only, *3*) excluding participants from the DM trial, as their diet may have changed over time, *4*) excluding incident type 2 diabetes diagnosed within the first 3 years of follow-up to address possible reverse causation, and *5*) excluding those with CVD or cancer at baseline, as these conditions may have resulted in dietary changes. In the subgroup analyses, we assessed associations between the Portfolio Diet score quintiles and incident type 2 diabetes according to age, BMI, family history of diabetes, self-identified race and ethnicity, and smoking status. *P* for interaction is for comparison of participants in quintile 1 (Q1) (low adherence) to Q5 (high adherence) of the Portfolio Diet score. Additional analyses included evaluation of associations between the six individual components of the Portfolio Diet and risk of type 2 diabetes. All statistical tests were two sided, and $P < 0.05$ was considered statistically significant. The statistical analyses were conducted with Stata statistical software (release 17; StataCorp, College Station, TX). Further information on methods can be found in Supplementary Material.

RESULTS

Lifestyle Characteristics of the Participants

Participant characteristics by quintiles of the dietary pattern scores are shown in Table 1. Overall, women with higher scores in all three dietary patterns tended to be older, have a lower BMI, engage in more physical activity, and have a higher education and were less likely to smoke, among other characteristics. Mean intake for the Portfolio, DASH, and Mediterranean diet score components are shown in Table 2 and Supplementary Tables 1 and 2. The Spearman rank correlation coefficients between the three dietary pattern scores ranged from 0.54 to 0.68 ($P < 0.001$ for all), with the Portfolio Diet score having a stronger correlation with the aMED score (0.68) than the DASH score (0.54).

Portfolio Diet and DASH and Mediterranean Diets and Incident Type 2 Diabetes

There were 13,943 cases reported of incident type 2 diabetes over a mean follow-up of 16.0 years. When comparing highest versus lowest quintiles in model 2, we observed an inverse association with incident type 2 diabetes for the Portfolio Diet (HR 0.77 [95% CI 0.72, 0.82], $P < 0.001$ for trend); DASH diet (0.69 [0.64, 0.73], $P < 0.001$ for trend); and aMED diet (0.78 [0.74, 0.83], $P < 0.001$ for trend) (Table 3). Additional adjustment for BMI in model 3 attenuated the risk by $\sim$10% but did not eliminate the inverse association for the Portfolio Diet (0.87 [0.82, 0.93], $P < 0.001$ for trend), DASH diet (0.78 [0.72, 0.83], $P < 0.001$ for trend), and aMED diet (0.88 [0.83, 0.94], $P < 0.001$ for trend). In addition, a 1-SD increase in the dietary scores was associated with a 6–8% lower risk of type 2 diabetes (0.94 [0.93, 0.96] for the Portfolio Diet, 0.92 [0.90, 0.93] for the DASH diet, and 0.94 [0.93, 0.96] for aMED diet), in the most adjusted models (Table 3). No significant nonlinear relationships were found between the three dietary pattern scores and risk of type 2 diabetes (Fig. 1 and Supplementary Figs. 1 and 3).

Sensitivity Analyses of the Portfolio Diet

The significant inverse associations between the Portfolio Diet score and incident type 2 diabetes remained similar (13–18% reduction comparing highest with lowest quintiles in model 3) in all sensitivity analyses, including when we excluded the CT participants (Supplementary Table 3).

Subgroup Analyses of the Portfolio Diet

The results remained largely consistent in each of the subgroup analyses, apart from smoking status, in which the inverse association was stronger but less precise in current smokers comparing the lowest and highest quintiles (Supplementary Fig. 3).

Table 1—Baseline characteristics of 145,299 participants initially free of type 2 diabetes in the WHI according to quintiles of the Portfolio Diet, DASH diet, and aMED diet

	Portfolio Diet			DASH diet			aMED*		
	Q1 (6.0–13.5)	Q3 (16.5–18.0)	Q5 (21.0–30.0)	Q1 (8.0–20.0)	Q3 (23.5–26.0)	Q5 (29.0–38.0)	Q1 (0–2.5)	Q3 (4.0–4.5)	Q5 (6.0–9.0)
Participants, *n* (%)	29,678 (20)	27,198 (23)	28,378 (20)	29,423 (20)	35,250 (24)	26,906 (19)	27,161 (19)	31,901 (22)	29,556 (20)
Time to event/censor (years)	15.3 (7.7)	16.1 (7.6)	16.4 (7.6)	14.8 (7.8)	16.2 (7.5)	16.8 (7.4)	14.9 (7.7)	16.0 (7.6)	16.9 (7.5)
Age (years)	62.6 (7.1)	63.2 (7.2)	63.6 (7.4)	61.6 (7.0)	63.4 (7.2)	64.3 (7.3)	62.8 (7.3)	63.1 (7.2)	63.4 (7.2)
BMI (kg/m^2)	28.6 (6.0)	27.8 (5.3)	26.6 (5.5)	29.3 (6.2)	27.6 (5.6)	26.0 (5.1)	28.7 (6.1)	27.8 (5.8)	26.7 (5.4)
Physical activity (MET h/week)	9.3 (11.8)	12.7 (13.5)	16.6 (15.5)	7.6 (10.7)	12.7 (13.3)	18.5 (15.9)	8.8 (11.6)	12.5 (13.4)	16.7 (15.0)
Dietary energy (kcal/day)	1,335 (502)	1,664 (618)	1,944 (662)	1,669 (676)	1,618 (646)	1,678 (571)	1,398 (558)	1,626 (613)	1,902 (643)
Region in the U.S., *n* (%)									
Northeast	9,052 (31)	6,036 (22)	4,719 (17)	6,976 (24)	8,050 (23)	6,208 (23)	6,827 (25)	7,329 (23)	6,487 (22)
South	7,478 (25)	6,928 (26)	6,790 (24)	9,414 (32)	8,394 (24)	5,864 (22)	7,205 (27)	8,047 (25)	7,022 (24)
Midwest	7,286 (25)	6,413 (24)	4,901 (17)	6,313 (21)	7,937 (23)	5,774 (21)	6,488 (24)	7,113 (22)	6,111 (21)
West	5,862 (20)	7,821 (29)	11,968 (42)	6,720 (23)	10,869 (31)	9,060 (34)	6,641 (24)	9,412 (30)	9,936 (34)
Self-identified race and ethnicity, *n* (%)									
White	24,468 (82)	23,392 (86)	23,988 (85)	21,615 (74)	30,707 (87)	24,611 (92)	22,253 (82)	26,985 (85)	26,094 (88)
African American	3,538 (12)	1,895 (7)	1,466 (5)	4,740 (16)	2,052 (6)	968 (4)	2,500 (9)	2,455 (8)	1,842 (6)
Hispanic	848 (3)	952 (4)	1,294 (5)	1,859 (6)	1,096 (3)	428 (2)	1,496 (6)	1,165 (4)	542 (2)
Asian	451 (2)	603 (2)	1,195 (4)	779 (3)	908 (3)	578 (2)	551 (2)	844 (3)	720 (2)
Alcoholic drinks (≥7/week†), *n* (%)	3,565 (12)	3,348 (12)	3,597 (13)	3,115 (11)	4,744 (14)	3,120 (12)	3,027 (11)	4,148 (13)	3,640 (12)
HT use, *n* (%)									
Never	10,887 (38)	8,423(31)	7,954 (29)	10,858 (38)	10,648 (31)	7,985 (31)	9,755 (37)	9,862 (32)	8,600 (30)
Past	6,994 (24)	5,913 (22)	6,221 (23)	7,007 (25)	7,714 (23)	5,933 (23)	6,430 (24)	6,968 (23)	6,413 (22)
Current	11,010 (38)	12,038 (48)	13,314 (48)	10,704 (37)	15,811 (46)	12,167 (47)	10,228 (39)	14,118 (46)	13,616 (48)
Hysterectomy ever, *n* (%)	12,430 (42)	11,229 (41)	11,204 (40)	13,120 (45)	13,446 (41)	10,111 (38)	11,693 (43)	13,120 (41)	11,461 (39)
Treated high cholesterol, *n* (%)	3,421 (12)	3,459 (14)	3,574 (13)	3,312 (12)	4,531 (14)	3,452 (13)	3,139 (12)	4,042 (13)	3,789 (14)
History of hypertension, *n* (%)	10,147 (34)	8,561(32)	8,067 (29)	10,323 (35)	11,190 (32)	7,338 (27)	9,123 (34)	10,177 (32)	8,615 (29)
Family history of diabetes, *n* (%)	9,339 (32)	8,342 (31)	8,061 (28)	9,839 (34)	10,570 (30)	7,465 (28)	8,585 (32)	9,806 (31)	8,468 (29)
Smoking status, *n* (%)									
Never	14,015 (47)	14,037 (52)	15,261 (54)	14,611 (50)	17,958 (51)	14,025 (52)	13,718 (51)	16,064 (50)	15,013 (51)
Past	12,284 (41)	11,530 (42)	12,090 (43)	10,855 (37)	15,331 (44)	12,156 (45)	10,353 (38)	13,736 (43)	13,437 (45)
Current	3,379 (11)	1,631 (6)	1,027 (4)	3,957 (13)	1,961 (6)	725 (3)	3,090 (11)	2,101 (7)	1,106 (4)
Education (college or above), *n* (%)	17,320 (59)	18,632 (69)	22,079 (78)	16,000 (55)	24,570 (70)	21,634 (81)	15,083 (56)	21,701 (69)	23,455 (80)
Marital status (present relationship), *n* (%)	17,677 (60)	17,497 (65)	17,951 (64)	17,860 (61)	22,829 (65)	16,490 (62)	16,203 (60)	20,239 (64)	19,251 (65)

Continued on p. 32

Table 1—Continued

	Portfolio Diet			DASH diet			aMED*		
	Q1 (6.0–13.5)	Q3 (16.5–18.0)	Q5 (21.0–30.0)	Q1 (8.0–20.0)	Q3 (23.5–26.0)	Q5 (29.0–38.0)	Q1 (0–2.5)	Q3 (4.0–4.5)	Q5 (6.0–9.0)
HT arm, *n* (%)									
Not randomized to HT	23,943 (81)	23,013 (85)	23,961 (84)	22,833 (78)	30,043 (85)	22,749 (85)	21,988 (81)	26,949 (84)	24,616 (83)
E-alone	1,157 (4)	818 (3)	727 (3)	1,391 (5)	957 (3)	695 (3)	1,064 (4)	951 (3)	840 (3)
E-alone control	1,210 (4)	728 (3)	844 (3)	1,465 (5)	898 (3)	700 (3)	1,089 (4)	924 (3)	856 (3)
E+P intervention	1,689 (6)	1,403 (5)	1,435 (5)	1,904 (6)	1,784 (5)	1,358 (5)	1,560 (6)	1,550 (5)	1,624 (5)
E+P control	1,679 (6)	1,236 (5)	1,411 (5)	1,830 (6)	1,568 (4)	1,404 (5)	1,460 (5)	1,527 (5)	1,620 (5)
DM arm, *n* (%)									
Not randomized to DM	19,757 (67)	18,885 (69)	20,018 (71)	16,465 (56)	24,301 (69)	22,381 (83)	17,974 (66)	22,174 (70)	20,834 (70)
Intervention	3,939 (13)	3,332 (12)	3,338 (12)	5,070 (17)	4,472 (13)	1,858 (7)	3,564 (13)	3,949 (12)	3,560 (12)
Control	5,982 (20)	4,981 (18)	5,022 (18)	7,888 (27)	6,477 (18)	2,667 (10)	5,623 (21)	5,778 (18)	5,162 (17)
CaD arm, *n* (%)									
Not randomized to CaD	22,395 (75)	21,145 (78)	22,139 (78)	20,444 (69)	27,358 (78)	22,385 (83)	20,471 (75)	24,828 (78)	22,745 (77)
Intervention	3,669 (12)	3,057 (11)	3,117 (11)	4,523 (15)	3,930 (11)	2,280 (8)	3,364 (12)	3,522 (11)	3,399 (12)
Control	3,614 (12)	2,996 (11)	3,122 (11)	4,456 (15)	3,962 (11)	2,241 (8)	3,326 (12)	3,551 (11)	3,412 (12)

Data are means (SD) unless otherwise indicated. E-alone, estrogen alone; E+P, estrogen plus progestin. *Quintiles for the aMED score were determined manually to provide more equal distribution of participants between quintiles. †The other category is <7 drinks per week, which includes those who drink no alcohol.

Individual Component Analyses of the Portfolio Diet

When we individually assessed the six components of the diet with incidence of type 2 diabetes, higher intake of viscous fiber sources (HR 0.93 [95% CI 0.87, 0.99]) and plant sterols (0.85 [0.78, 0.92]), and lower intake of saturated fat and dietary cholesterol sources (0.83 [0.77, 0.88]), were inversely associated with risk of type 2 diabetes in the most adjusted models (Supplementary Table 4). No significant associations were seen with plant protein, nuts, and MUFAs in relation to type 2 diabetes risk, although nut intake pointed in the direction of an inverse association (Supplementary Table 4).

CONCLUSIONS

Summary of Findings

In this large prospective cohort study of 145,299 postmenopausal women, comparing highest to lowest adherence, the Portfolio Diet score was associated with a 13% lower risk of type 2 diabetes. These findings remained generally consistent across all sensitivity and subgroup analyses, including when we excluded the WHI CT participants, highlighting the robustness of our findings. In addition, we found that comparing highest to lowest adherence of the DASH and aMED diets were associated with a 12–22% lower risk of type 2 diabetes.

The three dietary patterns scores were moderately to highly correlated, likely due to the overlap in many healthy food items between the dietary patterns, with the Portfolio and aMED diets showing the highest correlation (r = 0.68). The Portfolio and aMED diets may be more closely related due to the higher emphasis on MUFAs compared with saturated fat than the DASH diet. However, none of the scores were perfectly correlated, highlighting that each dietary pattern reflects some unique combination of foods. As each dietary pattern is scored differently, it is difficult to conclude that one pattern is better than another; however, the per 1 SD increase in the scores were all similarly (6–8%) associated with lower risk of incident type 2 diabetes. As adherence to diet is the most important determinant for patient success, health professionals should recommend evidence-based dietary patterns that best align with a patient's values and preferences (2).

Table 2—Scoring criteria for the Portfolio Diet score and daily intake for each quintile in the WHI

		Scoring criteria				
Component	Main targeted foods from WHI FFQ	Q1 (1 point)	Q2 (2 points)	Q3 (3 points)	Q4 (4 points)	Q5 (5 points)
Plant protein	Soy beverage, green peas, refried beans, all other beans, tofu and textured vegetable products, bean soups	0.05 (0.00–0.09)	0.13 (0.09–0.17)	0.21 (0.17–0.27)	0.34 (0.27–0.44)	0.77 (0.44–7.58)
Viscous fiber	Oranges, grapefruit, and tangerines; apples and pears; strawberries; okra; oats	0.14 (0.00–0.25)	0.38 (0.25–0.50)	0.64 (0.50–0.79)	0.98 (0.79–1.20)	1.78 (1.20–7.97)
Nuts	Peanut butter, peanuts, other nuts and seeds	0.00 (0.00–0.01)	0.04 (0.02–0.07)	0.10 (0.07–0.14)	0.23 (0.15–0.28)	0.62 (0.28–3.00)
Plant sterols	Estimated from all foods	133 (4–167)	190 (167–213)	235 (213–258)	287 (259–321)	403 (321–1,213)
MUFAs	Olive or canola oil, avocado and guacamole	0.00 (0.00–0.00)	*	0.01 (0.01–0.01)	0.03 (0.02–0.05)	0.24 (0.05–5.23)
Saturated fat/ cholesterol†	High-fat dairy, eggs, chicken/turkey with skin, red and processed meats, organ meats, gravy, butter	4.19 (2.55–21.3)	2.04 (1.61–2.54)	1.33 (1.07–1.61)	0.86 (0.64–1.07)	0.38 (0.00–0.64)

Data are means (range), where mean represents the mean of baseline and year 3 FFQ for OS participants and baseline for CT groups. Quintiles data for all components are reported as servings per day except for plant sterols, reported as milligrams per day. *Two points not given to any participants based on consumption of MUFAs (low in entire population). †Higher quintiles represent higher intake; however, high intake and high quintiles of saturated fat/cholesterol received lower scores.

Findings in the Context of Previous Literature

We are unaware of other studies with examination of the association of the Portfolio Diet with incident type 2 diabetes. Our findings are, however, consistent with previous research in which greater adherence to the Portfolio Diet was associated with reductions in intermediate risk factors for type 2 diabetes (23,24), including fasting plasma glucose, glycated hemoglobin (HbA_{1c}), BMI, and

Table 3—Prospective association of the Portfolio, DASH, and aMED dietary patterns with risk of type 2 diabetes among 145,299 participants in the WHI (CT + OS) (1993–2021)

	Q1	Q2	Q3	Q4	Q5	Per 1 SD increase	P_{trend}
Portfolio							
Median score	12.0	15.0	17.0	19.5	22.5		
Cases/person-years	3,221/452,805	3,473/537,932	2,609/438,987	2,289/425,443	2,351/466,426		
Model 1*	1.00 (ref)	0.92 (0.88, 0.96)	0.87 (0.83, 0.92)	0.80 (0.75, 0.84)	0.74 (0.70, 0.78)	0.89 (0.88, 0.91)	<0.001
Model 2†	1.00 (ref)	0.95 (0.90, 1.00)	0.90 (0.85, 0.95)	0.82 (0.77, 0.87)	0.77 (0.72, 0.82)	0.90 (0.88, 0.92)	<0.001
Model 3‡	1.00 (ref)	0.99 (0.94, 1.04)	0.94 (0.89, 0.99)	0.88 (0.83, 0.94)	0.87 (0.82, 0.93)	0.94 (0.93, 0.96)	<0.001
DASH							
Median score	18.0	22.0	25.0	27.5	30.5		
Cases/person-years	3,854/436,408	3,164/471,119	3,244/570,836	1,834/390,032	1,847/453,197		
Model 1*	1.00 (ref)	0.80 (0.77, 0.83)	0.69 (0.64, 0.73)	0.59 (0.56, 0.62)	0.51 (0.48, 0.54)	0.79 (0.77, 0.80)	<0.001
Model 2†	1.00 (ref)	0.90 (0.86, 0.95)	0.83 (0.79, 0.88)	0.75 (0.71, 0.80)	0.69 (0.64, 0.73)	0.88 (0.86, 0.90)	<0.001
Model 3‡	1.00 (ref)	0.93 (0.88, 0.98)	0.88 (0.84, 0.93)	0.81 (0.77, 0.86)	0.78 (0.72, 0.83)	0.92 (0.90, 0.93)	<0.001
aMED							
Median score	2.0	3.0	4.0	5.0	6.5		
Cases/person-years	2,957/406,039	2,951/446,685	3,106/509,383	2,518/460,847	2,411/498,638		
Model 1*	1.00 (ref)	0.93 (0.89, 0.98)	0.89 (0.83, 0.92)	0.80 (0.76, 0.84)	0.71 (0.68, 0.75)	0.88 (0.86, 0.89)	<0.001
Model 2†	1.00 (ref)	0.96 (0.90, 1.01)	0.92 (0.87, 0.97)	0.87 (0.82, 0.92)	0.78 (0.74, 0.83)	0.90 (0.89, 0.93)	<0.001
Model 3‡	1.00 (ref)	0.99 (0.94, 1.05)	0.97 (0.92, 1.02)	0.93 (0.88, 0.99)	0.88 (0.83, 0.94)	0.94 (0.93, 0.96)	<0.001

Data are HR (95% CI) unless otherwise indicated. Q1 represents the least adherent to the dietary patterns, whereas Q5 represents the most adherent. Association between dietary patterns and diabetes was determined by Cox proportional hazards models. Under/over–energy reporters and those with baseline diabetes were excluded from the analysis. *Model 1 adjustments include age (continuous), region (Northeast, South, Midwest, West), smoking (never, past, current) and study arm (HRT, DM, CaD). †Model 2 adjustments include model 1 adjustments plus self-identified race and ethnicity (White, African American, Hispanic, Asian), education (college or above, below college), marital status (presently married, other), hysterectomy history (yes, no), physical activity (continuous), alcohol intake (≥7 drinks/week, <7 drinks/week [excluded from aMED analysis, as alcohol intake is included in the score]), energy intake (continuous), hypertension status (yes, no), family history of diabetes (yes, no), HT use (never, past, current), cholesterol-lowering medication use (yes, no). ‡Model 3 adjustments include model 2 adjustments plus BMI (continuous).

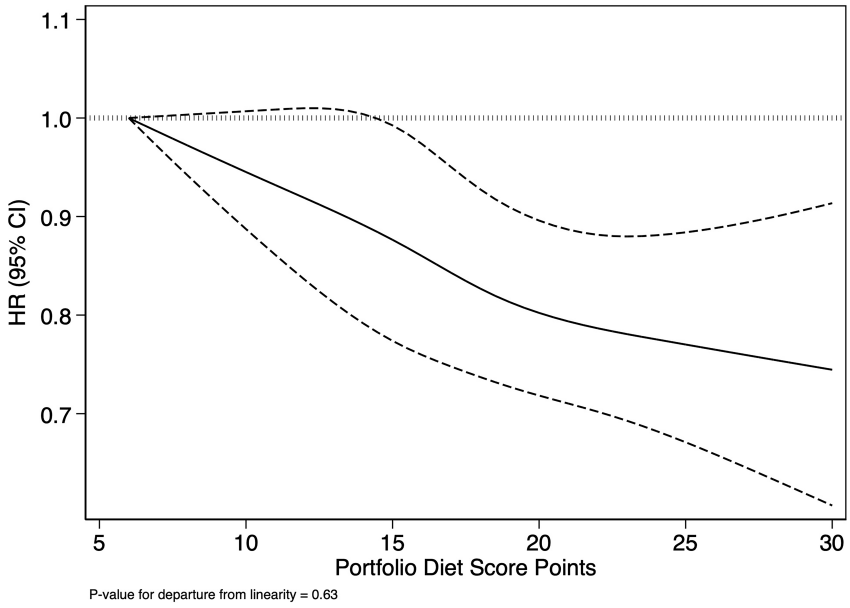

Figure 1—Restricted cubic splined multivariable-adjusted associations between Portfolio Diet score (continuous) and risk of type 2 diabetes. Cox proportional hazards regression included adjustment for age (continuous), region (Northeast, South, Midwest, West), smoking (never, past, current), study arm (HRT, DM, CaD), self-identified race and ethnicity (White, African American, Hispanic, Asian), education (college or above, below college), marital status (presently married, other), hysterectomy history (yes, no), physical activity (continuous), alcohol intake (≥7 drinks/week, <7 drinks/week), energy intake (continuous), hypertension status (yes, no), family history of diabetes (yes, no), HT use (never, past, current), cholesterol-lowering medication use (yes, no) and BMI (continuous). Horizontal interrupted line represents the reference HR (1.00).

waist circumference, in patients with metabolic syndrome over 1 year in the Prevención con Dieta Mediterránea (PREDIMED)-Plus cohort (7). The Portfolio Diet trials did not include assessment of markers of glycemic control and were not designed as weight loss studies (25); therefore, comparison with these trial results is difficult. Investigators of the Portfolio Diet trials did, however, observe a major reduction in a marker of inflammation, CRP (25), which has been associated with development of type 2 diabetes in prospective cohort studies, including the WHI (22,26). The results of the 3-year PortfolioEX trial (ClinicalTrials.gov identifier NCT02481466) of the effect of the Portfolio Diet plus exercise on a surrogate marker of atherosclerotic CVD risk (MRI of atherosclerosis [plaque volume]) will be of great interest once available, as this trial includes measurement of markers of glycemic control and will provide additional insight into the role of this diet regarding risk factors for type 2 diabetes.

Our findings are in line with previous literature assessing other healthy plant-based dietary patterns and type 2 diabetes risk (27,28). In a recent systematic review and meta-analysis of prospective cohort studies investigators found that plant-based diets were associated with 23% lower risk of type 2 diabetes—similar to our findings (27). In addition, the Mediterranean diet was shown to reduce incidence of type 2 diabetes in the PREDIMED-Reus trial (29). The Mediterranean diet and DASH diets have also been associated with an 18–19% reduction in type 2 diabetes risk in prospective cohort studies, which is similar to our findings for these two dietary patterns (30,31). Specifically, in the WHI, the DASH diet, Mediterranean diet, and Alternative Healthy Eating Index (AHEI) were previously associated with a 15–26% lower risk of type 2 diabetes in the OS participants only, and similar to our findings, BMI attenuated the risk estimates by ∼10%, highlighting that BMI could serve as a both a confounder and mediator in the relationship with type 2 diabetes (32).

Many of the individual components of the Portfolio Diet have also been associated with lower risk of type 2 diabetes in prospective cohort studies, including soy foods (33), viscous fiber sources such as oats (34), and peanut butter (35). However, the inverse association of increasing plant sterol intake from natural sources with incident type 2 diabetes has not been shown previously to the best of our knowledge. Interestingly, plant sterols have been shown to reduce adipose tissue and improve insulin sensitivity in animal models (36); further research in humans, however, is needed. The individual components of the Portfolio Diet have likewise been shown to improve intermediate risk factors for type 2 diabetes, including markers of glycemic control, insulin resistance, inflammation, body weight, and metabolic syndrome (37–41). The high viscous fiber content, low glycemic index, reduced intake of saturated fat, higher intake of plant MUFAs, increased intake of antioxidants and plant sterols, and higher intake of plant protein may contribute to the cardiometabolic benefits of the Portfolio Diet (3). In addition, the displacement of carbohydrates with MUFAs (as in the case of the Portfolio Diet + MUFA trial [42]) or nuts (43) may also improve intermediate risk factors for type 2 diabetes.

Strengths and Limitations

Strengths of our study include the prospective cohort design, large sample size, and long follow-up for incident type 2 diabetes. Nonetheless, our study has some limitations. Our study only included one or two self-reported dietary FFQ measurements, and therefore we could not measure dietary change. The population also included only postmenopausal women, and, thus, the results may not be generalizable to men or premenopausal women. Incident diabetes was also self-reported, and although this method has been shown to be valid with use of medical records and biomarkers (21,22), some cases may have been missed, as only medication-treated diabetes was determined. Moreover, as in all observational studies, residual confounding cannot be completely ruled out, even though we conducted a comprehensive assessment of the known diabetes risk factors in the WHI; however, this limitation will tend to attenuate the results. Lastly, consumption of some Portfolio Diet foods appeared low, particularly plant protein and MUFAs, which could have resulted in underestimation of the

magnitude of the association between the Portfolio Diet foods and diabetes risk, and a stronger inverse association with type 2 diabetes risk may be seen with greater consumption of the Portfolio Diet foods, as shown in previous studies of healthy plant-based dietary patterns (27). This finding of low level of consumption of certain foods suggests an opportunity for individuals to achieve cardiometabolic benefits of the Portfolio Diet and important implications for public health initiatives to help mitigate the global burden of type 2 diabetes and CVD, for which patients with type 2 diabetes are at higher risk. Despite this low consumption of some Portfolio Diet foods in the WHI population, we still observed a protective association with type 2 diabetes risk, alongside the DASH and aMED diets. This finding provides evidence that even small additions of Portfolio Diet foods to the diet may help lower the risk of diabetes, which may be a useful strategy for individuals who find consuming some components of the Portfolio Diet particularly challenging.

Conclusion

Greater adherence to the Portfolio, DASH, and aMED diets was significantly associated with a lower risk of type 2 diabetes in postmenopausal women. These findings represent the first prospective evidence showing the potential long-term benefits of a portfolio of plant-based foods known to lower circulating levels of cholesterol and CVD risk in the primary prevention of type 2 diabetes, although the findings need to be confirmed in other populations and randomized trials are needed. Overall, our results support the plant-based Portfolio Diet as another dietary approach for reducing type 2 diabetes risk among postmenopausal women along with the DASH and Mediterranean diets.

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He is a founding member of the International Carbohydrate Quality Consortium (ICQC), is the Chair of the Diabetes and Nutrition Study Group (DNSG) of the European Association for the Study of Diabetes (EASD), is on the Clinical Practice Guidelines Expert Committee for Nutrition Therapy of the EASD, and is a Director of Glycemia Consulting and the Toronto 3D Knowledge Synthesis and Clinical Trials foundation. 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