Higher Diet Quality Is Associated with Decreased Risk of All-Cause, Cardiovascular Disease, and Cancer Mortality among Older Adults[1,2]

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Abstract

Increased attention in dietary research and guidance has been focused on dietary patterns, rather than on single nutrients or food groups, because dietary components are consumed in combination and correlated with one another. However, the collective body of research on the topic has been hampered by the lack of consistency in methods used. We examined the relationships between 4 indices—the Healthy Eating Index–2010 (HEI-2010), the Alternative Healthy Eating Index–2010 (AHEI-2010), the alternate Mediterranean Diet (aMED), and Dietary Approaches to Stop Hypertension (DASH)—and all-cause, cardiovascular disease (CVD), and cancer mortality in the NIH-AARP Diet and Health Study (n = 492,823). Data from a 124-item food-frequency questionnaire were used to calculate scores; adjusted HRs and 95% CIs were estimated. We documented 86,419 deaths, including 23,502 CVD- and 29,415 cancer-specific deaths, during 15 y of follow-up. Higher index scores were associated with a 12–28% decreased risk of all-cause, CVD, and cancer mortality. Specifically, comparing the highest with the lowest quintile scores, adjusted HRs for all-cause mortality for men were as follows: HEI-2010 HR: 0.78 (95% CI: 0.76, 0.80), AHEI-2010 HR: 0.76 (95% CI: 0.74, 0.78), aMED HR: 0.77 (95% CI: 0.75, 0.79), and DASH HR: 0.83 (95% CI: 0.80, 0.85); for women, these were HEI-2010 HR: 0.77 (95% CI: 0.74, 0.80), AHEI-2010 HR: 0.76 (95% CI: 0.74, 0.79), aMED HR: 0.76 (95% CI: 0.73, 0.79), and DASH HR: 0.78 (95% CI: 0.75, 0.81). Similarly, high adherence on each index was protective for CVD and cancer mortality examined separately. These findings indicate that multiple scores reflect core tenets of a healthy diet that may lower the risk of mortality outcomes, including federal guidance as operationalized in the HEI-2010, Harvard's Healthy Eating Plate as captured in the AHEI-2010, a Mediterranean diet as adapted in an Americanized aMED, and the DASH Eating Plan as included in the DASH score. J. Nutr. 144: 881–889, 2014.

Introduction

Increased attention in dietary research and guidance has been focused on dietary patterns, rather than on single nutrients or food groups (1), because dietary components are consumed in combination and correlated with one another. However, the collective body of research on the topic has been hampered by the lack of consistency in methods used, including variation in the underlying constructs selected, metrics used, and modeling decisions. Because of these limitations, both the 2007 World Cancer Research Fund Report (2) and the 2010 Dietary Guidelines Advisory Committee (3) concluded that the evidence was not sufficient to draw firm conclusions regarding the role of dietary patterns and health outcomes such as cardiovascular disease (CVD)[8] and cancer. Thus, the National Cancer Institute initiated the Dietary Patterns Methods Project (DPMP) to strengthen the scientific evidence base relating dietary patterns to mortality through the conduct of simultaneous analyses in 3 established U.S. cohorts, all using identical methods and models.

As part of the DPMP, we systematically examined 4 indices—the Healthy Eating Index–2010 (HEI-2010) (4), the Alternative Healthy Eating Index–2010 (AHEI-2010) (5), the alternate

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[2] Supplemental Figure 1 and Supplemental Tables 1–6 are available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at http://jn.nutrition.org.

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[8] Abbreviations used: AHEI-2010, Alternative Healthy Eating Index–2010; aMED, alternate Mediterranean Diet; CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension; DPMP, Dietary Patterns Methods Project; HEI-2010, Healthy Eating Index–2010.

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Mediterranean Diet (aMED) score (6), and the Dietary Approaches to Stop Hypertension (DASH) score (7)—and their associations with all-cause, CVD, and cancer mortality among older adults in the United States using the NIH-AARP Diet and Health Study as the data source. Index scores, which use standards and cutoffs defined a priori on the basis of scientific findings, were selected because they are most readily translatable to dietary guidance. In contrast, data-driven approaches, such as factor or cluster analysis, create factor scores based on the underlying variation in food reported or identify clusters of people based on similar intake. These a posteriori methods vary depending on the population under investigation and are more complex to standardize and compare across cohorts and population groups.

Participants and Methods

Project overview. We used data from the NIH-AARP Diet and Health Study, a prospective cohort study designed to investigate diet and cancer. AARP members who were between the ages of 50 and 71 y and who were residents of 6 states (California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania) or 2 metropolitan areas (Atlanta, GA, and Detroit, MI) were contacted in 1995–1996 to participate in the NIH-AARP Diet and Health Study; the response rate was 17.6% (8). Of the 566,398 satisfactorily completed questionnaires, we excluded questionnaires completed by proxy (n = 15,760), respondents with previous cancer (n = 53,588) or heart disease (n = 68,588), and individuals with extreme caloric intake (>2 IQRs above the 75th percentile or below the 25th percentile on the logarithmic scale; n = 3,800) (9). The final analytic cohort included 424,662 people.

Cohort follow-up and mortality ascertainment. Study participants were followed from enrollment in 1995–1996 through 31 December 2011. Addresses were updated periodically by matching the cohort database to the National Change of Address maintained by the U.S. Postal Service and other address change update services, and by direct communication with participants (10). Vital status was determined by annual linkage of the cohort to the Social Security Administration Death Master File on deaths in the United States, follow-up searches of the National Death Index for participants who correspond to the Social Security Administration Death Master File, cancer registry linkage, and responses to questionnaires and other mailings. We investigated cause-specific mortality, including CVD and cancer mortality, by using the Surveillance Epidemiology and End Results coding system (11). The NIH-AARP Diet and Health Study was approved by the Special Studies Institutional Review Board of the National Cancer Institute.

Exposure assessment. Study participants completed the AARP 124-item FFQ (AARP-FFQ), an early version of the Diet History Questionnaire, to assess dietary intake over the past year. The Diet History Questionnaire has been calibrated (8,12), and further validation was performed by using two 24-h recalls within a subset of the NIH-AARP Diet and Health Study (13).

To create components for all of the scores, we used guidance-based food group equivalents and nutrient variables from the AARP-FFQ. We merged the MyPyramid Equivalents Database (MPED), version 1.0, with the AARP-FFQ data to derive guidance-based food group equivalents for whole grains, total grains, total vegetables, (including all vegetable subgroups), total fruit, low-fat dairy, protein foods (including poultry, fish, nuts, soy, and legumes), solid fat, added sugars, and alcohol. We also created variables for vegetables (excluding white potatoes), red and processed meat, whole fruit, sugar-sweetened beverages, and energy from alcohol. Additionally, we generated nutrient estimates for SFAs, PUFAs, MUFAs, *trans* fat, EPA (20:5n−3), DHA (22:6n−3), sodium, and alcohol by using the USDA Survey Nutrient Database associated with the Continuing Survey for Food Intake by Individuals 1994–96 and the Nutrition Data System for Research. By using the guidance-based food group equivalents and other nutrient variables, we calculated component and index scores for the HEI-2010, AHEI-2010, aMED, and DASH on the basis of published descriptions of the indices, converting standards to cup and ounce equivalents as needed. **Table 1** identifies the components and standards for optimal scoring; specific details are described below.

HEI-2010. The HEI was developed to quantify adherence to federal dietary guidance (14). We used a version that aligns with the 2010 *Dietary Guidelines for Americans* (4). The HEI-2010 scores 12 components for a total of 100 points. Six components—total vegetables, "greens and beans" (dark green vegetables and any legumes that are not already counted as protein foods), total fruit, whole fruit, seafood and plant proteins, and total protein foods—are worth 0–5 points; 5 components—whole grains, low-fat dairy, FA ratio [(PUFA+MUFA): SFA], refined grains, and sodium—are worth 0–10 points; and 1 component—"empty calories" (energy from solid fats, added sugars, and any alcohol in excess of 13 g/1000 kcal)—is worth 0–20 points. All components except for the FA ratio are scored on a density basis (per 1000 kcal or as a percentage of energy).

AHEI-2010. The AHEI was developed based on foods and nutrients associated with chronic disease risk drawn from extensive epidemiologic studies (15–17). We used the updated version of the AHEI-2010 (5). The AHEI-2010 scores 11 components for a total of 110 points. Each component—whole grains, vegetables (excluding potatoes), fruit, nuts and legumes, *trans* fat, EPA + DHA (n–3 FAs), PUFAs, alcohol, red and processed meat, sugar-sweetened beverages and fruit juices, and sodium—is worth 0–10 points.

aMED score. The first Mediterranean diet score was developed based on key findings from epidemiologic studies in Europe from the 1960s that investigated mortality risk factors (18). The score we used, aMED, was adapted for use in an American population (6). The aMED scores 9 components for a total of 9 points. One point is scored for intake at or greater than the sex-specific median for whole grains, vegetables (excluding potatoes), fruit, nuts, legumes, fish, and FA acid ratio (MUFA: SFA); and 1 point is given for intakes less than the sex-specific median for red and processed meat (median values are presented in Table 1). Alcohol is based on predetermined cutoffs.

DASH score. The DASH score was designed to capture the diet tested in 2 DASH randomized controlled feeding trials (19,20), which examined the role of dietary patterns on blood pressure. Several versions of the DASH score exist, and we used the one most commonly found in the literature with U.S. populations (7). DASH scores 8 components (7 food groups and 1 nutrient)—each worth 5 points—for a total of 40 points. The scoring system is based on sex-specific quintile rankings within the study population. Points range from 5 (highest quintile) to 1 (lowest quintile) for whole grains, vegetables (excluding potatoes), fruit, nuts and legumes, and low-fat dairy, and from 1 (highest quintile) to 5 (lowest quintile) for sodium, sugar-sweetened beverages, and red and processed meat.

Statistical analysis. We used descriptive statistics to examine the characteristics of the study population and estimate correlation coefficients between indices. Cox proportional hazards models (21) with person-years as the underlying time metric were used to model the HRs of all-cause mortality. We also conducted models to investigate associations for CVD and cancer mortality as separate outcomes. Additional analyses were conducted to examine the independent associations between the individual components of each index and each outcome. Separate Cox proportional hazards models were performed for each component (component i), adjusting for specified covariates and a modified total index score that did not include the respective component (modified total index score = total index score − component i). SAS statistical software (version 9.2; SAS Institute) was used for all analyses.

We adjusted for the following covariates and potential risk factors: age (y), ethnicity (white, black, other), education (less than high school, high school, some college, college graduate), BMI (18.5 to <25, 25 to <30, 30 to <35, 35 to <40, ≥40 kg/m^2), smoking (never smoker, former

TABLE 1 Scoring standards for each component of the HEI-2010, AHEI-2010, aMED, and DASH score using standardized cup and ounce equivalents[1]

	HEI-2010[2]		AHEI-2010[3]		aMED[4]		DASH[5]	
Component	Criteria for minimum score	Criteria for maximum score	Criteria for minimum score	Criteria for maximum score	Criteria for minimum score	Criteria for maximum score	Criteria for minimum score	Criteria for maximum score
Whole grains	0 oz eq/1000 kcal	≥1.5 oz eq/1000 kcal	0 oz eq/d	≥5 and ≥6 oz eq/d (men and women)	Less than median	Median or greater	Lowest quintile	Highest quintile
Total vegetables, *cup eq/1000 kcal*	0	≥1.1	—	—	—	—	—	—
Vegetables excluding potatoes, *cup eq/d*	—	—	0	≥2.5	Less than median	Median or greater	Lowest quintile	Highest quintile
Greens and beans,[6] *cup eq/1000 kcal*	0	≥0.2	—	—	—	—	—	—
Total fruit	0 cup eq/1000 kcal	≥0.8 cup eq/1000 kcal	0 cup eq/d	≥2 cup eq/d	Less than median	Median or greater	Lowest quintile	Highest quintile
Whole fruit, *cup eq/1000 kcal*	0	≥0.4	—	—	—	—	—	—
Nuts and legumes, *oz eq/d*	—	—	0	≥1	—	—	Lowest quintile	Highest quintile
Nuts	—	—	—	—	Less than median	Median or greater	—	—
Legumes	—	—	—	—	Less than median	Median or greater	—	—
Seafood and plant proteins, *oz eq/1000 kcal*	0	≥0.8	—	—	—	—	—	—
Fish	—	—	—	—	Less than median	Median or greater	—	—
Total protein foods, *oz eq/1000 kcal*	0	≥2.5	—	—	—	—	—	—
Low-fat dairy, *cup eq/1000 kcal*	0	≥1.3	—	—	—	—	Lowest quintile	Highest quintile
FA ratio	PUFA+MUFA:SFA, <1.2	PUFA+MUFA:SFA, ≥2.5	—	—	MUFA:SFA, less than median	MUFA:SFA, median or greater	—	—
trans fat, *%*	—	—	≥4	≤0.5	—	—	—	—
EPA + DHA, *mg/d*	—	—	0	250	—	—	—	—
PUFAs, *%*	—	—	≤2	≥10	—	—	—	—
Alcohol	—	—	≥3.5 and ≥2.5 drinks/d (men and women)	0.5–2 and 0.5–1.5 drinks/d (men and women)	<5 or >15 and <10 or >25 g/d (men and women)	5–15 and 10–25 g/d (men and women)	—	—
Red and processed meat, *oz eq/d*	—	—	≥1.5	0	Median or greater	Less than median	Highest quintile	Lowest quintile
Refined grains, *oz eq/1000 kcal*	≥4.3	≤1.8	—	—	—	—	—	—
Empty calories,[7] *% of kcal*	≥50	≤19	—	—	—	—	—	—
Sugar-sweetened beverages and fruit juices, *cup eq/d*	—	—	≥1	0	—	—	—	—
Sugar-sweetened beverages	—	—	—	—	—	—	Highest quintile	Lowest quintile
Sodium, *g/1000 kcal*	≥2.0	≤1.1	Highest decile	Lowest decile	—	—	Highest quintile	Lowest quintile

[1] Scoring standards are based on cup and ounce equivalents from the MyPyramid Equivalents Database: 1 oz = 28.3 g, 1 cup = 225 mL. AHEI-2010, Alternative Healthy Eating Index–2010; aMED, alternate Mediterranean Diet; DASH, Dietary Approaches to Stop Hypertension; eq, equivalent; HEI-2010, Healthy Eating Index–2010; —, not applicable.
[2] HEI-2010: 100 points total; 12 components: 5–20 points each. Components are given different point values and prorated based on minimum and maximum scores: whole grains (10 points), total vegetables (5 points), ''greens and beans'' (5 points), total fruit (5 points), whole fruit (5 points), seafood and plant proteins (5 points), total protein foods (5 points), low-fat dairy (10 points), FA ratio (10 points), refined grains (10 points), empty calories (20 points, includes energy from solid fats, added sugars, and any alcohol in excess of 13 g/1000 kcal), and sodium (10 points).
[3] AHEI-2010: 110 points total; 11 components: 10 points each. Components are prorated based on minimum and maximum scores.
[4] aMED: 9 points total; 9 components: 1 point each. Median values for each component for men and women, respectively: whole grains (0.87 and 0.72 oz eq/d), vegetables excluding potatoes (1.32 and 1.34 cup eq/d), total fruit (1.67 and 1.67 cup eq/d), nuts (0.28 and 0.17 oz eq/d), legumes (0.07 and 0.04 oz eq/d), fish (0.49 and 0.37 oz eq/d), FA ratio (1.23 and 1.22), alcohol (cutoffs: 5–15 and 10–25 g/d), and red and processed meat (2.24 and 1.27 oz eq/d).
[5] DASH: 40 points total; 8 components: 5 points each. Median values for optimal quintile for each component for men and women, respectively: whole grains (2.13 and 1.75 oz eq/d), vegetables excluding potatoes (3.47 and 3.40 cup eq/d), total fruit (3.95 and 3.83 cup eq/d), nuts and legumes (1.55 and 0.96 oz eq/d), low-fat dairy (2.97 and 2.70 cup eq/d), red and processed meat (0.74 and 0.37 oz eq/d), sugar-sweetened beverages (0 and 0 cup eq/d), and sodium (1620 and 1240 mg/d).
[6] Greens and beans are dark green vegetables and any legumes that are not already counted as protein foods.
[7] Empty calories are defined as energy from solid fats, added sugars, and any alcohol in excess of 13 g/1000 kcal.

smoker of ≤1 pack/d, former smoker of >1 pack/d, current smoker of ≤1 pack/d, current smoker of >1 pack/d), vigorous physical activity (≥20 daily minutes reported rarely or never, 1–3 times/mo, 1–2 times/wk, 3–4 times/wk, ≥5 times/wk), energy intake (kcal), marital status (married, widowed, divorced, separated, never married), and diabetes. Alcohol (g) was adjusted in the HEI-2010 and DASH models only because both AHEI-2010 and aMED consider alcohol as a separate component; and menopausal hormone therapy use was included as a covariate only among women. Missing values were included in the model as dummy variables, similar to the way valid categories were represented. Energy was included in the final models for all indices to reduce measurement error and allow for comparability, particularly because only 1 index (HEI-2010) controls for energy intake by design. We conducted models with and without energy and the estimates did not change appreciably. Potential effect modification was explored with age, BMI, and smoking. We present final models with age, BMI, and smoking as covariates because this was an a priori decision for comparability across cohorts, and importantly, estimates did not change appreciably in the stratified models. Last, we conducted models with and without BMI due to consideration of the potential role of body weight as a mediator in the pathway, and estimates did not change appreciably.

Results

During 15 y of follow-up, 86,419 deaths were documented, including 23,502 CVD deaths (15,497 for men and 8005 for women) and 29,415 cancer deaths (18,646 for men and 10,769 for women).

Table 2 shows characteristics of the men and women in the highest quintile (quintile 5; most optimal diet quality) compared with the lowest quintile (quintile 1; poorest diet quality) for each diet quality index. Across all indices, both men and women in quintile 5 were more likely to be older, leaner, more physically active, and college graduates. Men in quintile 5 were also consistently more likely to be married and never to have smoked; this was similar for women, with few exceptions. For HEI-2010, AHEI-2010, and aMED, men and women in quintile 5 had higher intakes of alcohol; in contrast, for DASH, men and women in quintile 5 had lower intakes of alcohol. For aMED and DASH, men and women in quintile 5 had higher energy intakes; this was also found in AHEI-2010 for women.

Correlations among the total scores for all pairs of indices are presented in **Table 3**. For men, the correlations ranged from 0.53 (for HEI-2010 and aMED) to 0.69 (for HEI-2010 and DASH). For women, the correlations ranged from 0.49 (for HEI-2010 and aMED) to 0.62 (for HEI-2010 and DASH). All correlations were significant ($P < 0.0001$).

Supplemental Figure 1 shows that, across all indices, men and women in quintile 5 compared with quintile 1 had a 12–28% decreased risk of all-cause, CVD, and cancer mortality. For both men and women, when comparing quintile 5 to quintile 1, the direction and magnitude of the adjusted HRs consistently indicated a protective association for all-cause, CVD, and cancer mortality. For example, the HRs for all-cause mortality for men were as follows: HEI-2010 HR: 0.78 (95% CI: 0.76, 0.80), AHEI-2010 HR: 0.76 (95% CI: 0.74, 0.78), aMED HR: 0.77 (95% CI: 0.75, 0.79), and DASH HR: 0.83 (95% CI: 0.80, 0.85); for women these were HEI-2010 HR: 0.77 (95% CI: 0.74, 0.80), AHEI-2010 HR: 0.76 (95% CI: 0.74, 0.79), aMED HR: 0.76 (95% CI: 0.73, 0.79), and DASH HR: 0.78 (95% CI: 0.75, 0.81). **Tables 4** and **5** provide additional details for each quintile in these full models.

In the by-components models, different components were independently associated with mortality outcomes (**Supplemental Tables 1–6**). Overall, results for the analyses of individual components were consistent with the results from the total index score analysis. There were a few unexpected findings; for example, for all-cause mortality: increased risk was found among both men and women with higher scores on the HEI-2010 refined grain component (indicating lower consumption), for men with higher scores on the AHEI-2010 sugar-sweetened beverages and fruit juice component (indicating lower consumption), and for men on the AHEI-2010 and DASH sodium components (indicating lower consumption based on deciles and quintiles of intake).

Discussion

We found a 12–28% reduced risk of all-cause, CVD, and cancer mortality for men and women in the NIH-AARP Diet and Health Study, which was similar across all 4 diet quality indices—HEI-2010, AHEI-2010, aMED, and DASH. To our knowledge, there are no previous studies in the literature that have compared these specific indices within the same U.S. cohort for cause-specific mortality outcomes. This study has the potential to inform both policy makers and those developing dietary guidelines as to the role of dietary patterns in health.

Although approximately one dozen studies have examined the associations of specific diet quality indices with mortality, the literature has been complex to summarize (22). This challenge stems from the lack of standardization within a specific index as it is applied in different analyses and the total number of indices that exist; moreover, relatively few studies were able to examine diet quality and cause-specific mortality outcomes in U.S. populations. There are consistent and protective associations for the Mediterranean diet and mortality, but in the 10 studies investigating this relations there are 8 different versions of the "Mediterranean Diet Score" (18,23–31). These modifications were sometimes made to account for population-specific consumption patterns (e.g., alterations to best capture the constructs as intended based on food sources of FAs), but the variations also alter the definition and scoring of some components, delete entire components such as alcohol and dairy, combine components, create new components, or make different decisions regarding energy adjustment. Other U.S.-based indices, such as the HEI-2010 and AHEI-2010, have also been intentionally updated as recently as 2012, making it challenging to compare studies using these indices as well. Additionally, we found 11 other unique diet quality indices applied to mortality outcomes: Recommended Food Score (26,31,32), Recommended Foods and Behavior Score (33), Overall Healthy Diet Index (25), Healthy Diet Indicator (26), Dietary Behavior Score (33), Healthy Eating Index–2005 (34), Dietary Behavior Score (35), Alternative Healthy Eating Index–2005 (36), American Cancer Society Score (37), Dietary Diversity Score (38), Dietary Index–Revised (38), and Healthy Diet Score (31). Some of the indices examined showed inverse associations for all-cause and CVD mortality but not cancer mortality (30,36); some studies were not able to examine cause-specific mortality at all because of the low number of deaths.

All 4 diet quality indices that we examined showed similar associations with mortality. However, among men, the AHEI-2010 appeared to have a stronger relation with CVD mortality than for cancer mortality, whereas the opposite was true for the HEI-2010 (stronger relation for cancer mortality than for CVD mortality). Because of variations in the definitions of optimal diet quality and scoring, these scores categorize some but not all of the same participants in the same quintiles (as evidenced by

TABLE 2 Descriptive characteristics of men (*n* = 242,321) and women (*n* = 182,342) in the NIH-AARP Diet and Health Study based on lower and upper quintiles of the HEI-2010, AHEI-2010, aMED, and DASH score[1]

	HEI-2010		AHEI-2010		aMED		DASH	
	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5
Men								
Range of index points	18.2–55.2	74.1–96.1	12.8–43.5	60.5–92.1	0–2	6–9	8–20	28–37
n	48,464	48,464	48,464	48,464	44,456	59,449	50,466	46,151
Mortality, *no. of cases*	13,746	9245	13,109	8964	11,980	11,470	12,884	9166
CVD	3633	2704	3718	2476	3335	3273	3521	2687
Cancer	4880	3039	4364	3133	3953	3888	4546	2938
Age, *y*	61.3 ± 0.02	63.1 ± 0.02	61.7 ± 0.02	62.6 ± 0.02	61.9 ± 0.03	62.5 ± 0.02	61.1 ± 0.02	63.0 ± 0.02
Ethnicity, *% white*	92.3	92.6	92.6	92.3	92.1	92.5	90.4	93.3
BMI, *kg/m²*	26.7 ± 0.02	25.9 ± 0.02	26.8 ± 0.02	26.0 ± 0.02	26.8 ± 0.02	26.3 ± 0.02	26.8 ± 0.02	25.9 ± 0.02
Energy intake, *kcal/d*	2140 ± 4.75	1740 ± 3.13	1990 ± 4.15	1850 ± 3.57	1530 ± 3.61	2220 ± 3.52	1830 ± 3.83	2010 ± 3.80
Physical activity ≥5 times/wk, *%*	15.1	28.6	15.2	29.0	14.4	27.7	13.7	31.2
Smoking, *% never smoked*	23.1	36.6	28.1	32.5	26.8	34.5	24.9	36.8
Education, *% college graduate*	31.9	55.7	34.6	57.0	36.9	53.3	35.3	54.9
Marital status, *% married*	82.3	85.0	83.8	84.6	82.7	85.9	84.0	84.2
Diabetes, *% yes*	5.8	9.3	7.2	8.2	8.4	7.6	6.2	9.5
Alcohol, *g/d*	2.9	4.4	1.8	9.7	2.1	6.2	4.3	3.1
Women								
Range of index points	18.5–59.3	76.4–96.2	17.6–44.7	60.7–90.7	0–2	6–9	9–20	28–37
n	36,468	36,468	36,468	36,468	32,521	44,474	38,546	35,431
Mortality, *no. of cases*	8038	5249	7685	5124	6734	6420	7940	5216
CVD	1987	1374	2000	1229	1715	1674	2030	1379
Cancer	2720	1837	2471	1940	2283	2261	2723	1771
Age, *y*	61.1 ± 0.03	63.1 ± 0.03	61.8 ± 0.03	62.0 ± 0.03	61.9 ± 0.03	62.2 ± 0.03	61.2 ± 0.03	62.8 ± 0.03
Ethnicity, *% white*	89.8	89.1	89.2	90.3	90.8	87.9	87.4	90.2
BMI, *kg/m²*	26.0 ± 0.03	24.9 ± 0.03	26.2 ± 0.03	24.7 ± 0.03	25.9 ± 0.03	25.1 ± 0.03	26.0 ± 0.03	24.9 ± 0.03
Energy intake, *kcal/d*	1570 ± 3.97	1390 ± 2.94	1480 ± 3.36	1520 ± 3.42	1110 ± 2.78	1800 ± 3.24	1330 ± 3.07	1650 ± 3.52
Physical activity ≥5 times/wk, *%*	10.2	22.9	10.6	24.1	10.7	21.8	9.5	25.2
Smoking, *% never smoked*	39.1	47.9	45.4	40.8	41.7	46.7	39.5	48.4
Education, *% college graduate*	21.2	37.9	22.2	40.4	23.2	37.1	22.2	38.5
Marital status, *% married*	41.7	45.3	43.2	45.7	41.7	47.0	45.7	41.7
HRT, *% past/current*	46.6	57.6	47.6	58.4	49.6	56.1	49.1	55.9
Diabetes, *% yes*	5.2	6.3	6.4	5.5	6.4	5.5	5.2	6.5
Alcohol, *g/d*	0.7	1.1	0.5	2.0	0.7	1.3	0.9	0.5

[1] Values are medians ± SDs unless otherwise specified. AHEI-2010, Alternative Healthy Eating Index–2010; aMED, alternate Mediterranean Diet; CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension; HEI-2010, Healthy Eating Index–2010; HRT, hormone replacement therapy; Q, quintile.

the correlations). There are common constructs across these indices, but each was designed to capture a slightly different pattern. The core similarities are that all 4 indices emphasize whole grains, vegetables, fruit, and plant-based proteins. The differences relate to several issues. Some are a result of differences in the interpretation of the scientific evidence, as with alcohol (39,40) and low-fat dairy (41,42), whereas others appear to be due to decisions regarding how to best operationalize a related construct (red/processed meat and FAs), or constraints in the initial diet assessment tool with which the index was developed (e.g., methods for capturing intakes of sugars and sodium). Alcohol has been associated with positive and negative outcomes, so it is understandable that there are varying approaches (in the AHEI-2010 and aMED, moderate alcohol intake is a separate component necessary for optimal diet quality; in the HEI-2010, excessive intake of alcohol energy is penalized; DASH ignores alcohol). Similarly, the specific criteria for low-fat dairy vary across the indices (in the HEI-2010 and DASH, it is a beneficial component, but the aMED and AHEI-2010 do not include it). When examining these components separately, we found a protective or null effect for all 3 outcomes with moderate alcohol and low-fat dairy. For both alcohol and dairy, intake may benefit some but not all population subgroups in relation to various outcomes. Future analyses by the DPMP collaborative group aim to explore these complex issues in greater detail.

TABLE 3 Correlation coefficients among total summary scores for the HEI-2010, AHEI-2010, aMED, and DASH score for men (*n* = 242,321) and women (*n* = 182,342) in the NIH-AARP Diet and Health Study[1]

	HEI-2010		AHEI-2010		aMED		DASH	
	Men	Women	Men	Women	Men	Women	Men	Women
HEI-2010	1.00	1.00						
AHEI-2010	0.62	0.55	1.00	1.00				
aMED	0.53	0.49	0.59	0.56	1.00	1.00		
DASH	0.69	0.62	0.60	0.57	0.63	0.61	1.00	1.00

[1] All $P < 0.0001$. AHEI-2010, Alternative Healthy Eating Index–2010; aMED, alternate Mediterranean Diet; DASH, Dietary Approaches to Stop Hypertension; HEI-2010, Healthy Eating Index–2010.

TABLE 4 Multivariate HRs (95% CIs) for mortality according to quintiles of diet quality indices for the HEI-2010, AHEI-2010, aMED, and DASH score among men (n = 242,321) in the NIH-AARP Diet and Health Study[1]

Index and quintile	Range of index score[2]	Men	Any deaths	Follow-up	All-cause mortality	CVD deaths	CVD mortality	Cancer deaths	Cancer mortality
		n	*n*	*person-years*		*n*		*n*	
HEI-2010									
1	18.2–55.2	48,464	13,746	643,181	1.00	3633	1.00	4880	1.00
2	55.2–62.6	48,464	11,449	656,332	0.91 (0.88, 0.93)	3250	0.95 (0.91, 1.00)	3936	0.90 (0.86, 0.94)
3	62.6–68.3	48,465	10,523	662,729	0.86 (0.83, 0.88)	3009	0.90 (0.86, 0.95)	3579	0.85 (0.82, 0.89)
4	68.3–74.1	48,464	9908	664,187	0.83 (0.81, 0.85)	2901	0.89 (0.85, 0.94)	3212	0.79 (0.75, 0.83)
5	74.1–96.1	48,464	9245	668,900	0.78 (0.76, 0.80)	2704	0.85 (0.80, 0.89)	3039	0.76 (0.72, 0.80)
AHEI-2010									
1	12.8–43.5	48,464	13,109	647,038	1.00	3718	1.00	4364	1.00
2	43.5–49.3	48,464	11,665	655,015	0.91 (0.89, 0.93)	3253	0.88 (0.84, 0.93)	3966	0.94 (0.90, 0.98)
3	49.3–54.4	48,464	10,976	658,876	0.88 (0.86, 0.91)	3182	0.89 (0.85, 0.93)	3674	0.90 (0.87, 0.95)
4	54.4–60.5	48,464	10,157	663,995	0.83 (0.81, 0.86)	2868	0.82 (0.78, 0.86)	3509	0.89 (0.85, 0.93)
5	60.5–92.1	48,464	8964	670,405	0.76 (0.74, 0.78)	2476	0.74 (0.70, 0.78)	3133	0.82 (0.78, 0.86)
aMED									
1	0–2	44,456	11,980	593,183	1.00	3335	1.00	3953	1.00
2	3	43,164	10,448	583,452	0.92 (0.90, 0.94)	2900	0.92 (0.87, 0.97)	3663	0.98 (0.93, 1.02)
3	4	49,229	11,182	668,618	0.88 (0.85, 0.90)	3196	0.90 (0.86, 0.95)	3789	0.91 (0.87, 0.95)
4	5	46,023	9791	629,541	0.83 (0.81, 0.85)	2793	0.85 (0.81, 0.90)	3353	0.87 (0.83, 0.91)
5	6–9	59,449	11,470	820,535	0.77 (0.75, 0.79)	3273	0.80 (0.76, 0.84)	3888	0.80 (0.77, 0.84)
DASH									
1	8–20	50,466	12,884	678,105	1.00	3521	1.00	4546	1.00
2	21–22	39,139	9346	530,136	0.95 (0.92, 0.97)	2632	0.95 (0.90, 1.00)	3207	0.94 (0.89, 0.98)
3	23–24	45,424	10,287	618,493	0.90 (0.88, 0.93)	2903	0.91 (0.86, 0.95)	3531	0.91 (0.87, 0.95)
4	25–27	61,141	13,188	834,945	0.87 (0.85, 0.90)	3754	0.88 (0.84, 0.92)	4424	0.87 (0.84, 0.91)
5	28–37	46,151	9166	633,651	0.83 (0.80, 0.85)	2687	0.86 (0.81, 0.91)	2938	0.80 (0.76, 0.84)

[1] Adjusted for age, race/ethnicity, education, marital status, physical activity, smoking, energy intake, BMI, diabetes, and alcohol (HEI-2010 and DASH only). AHEI-2010, Alternative Healthy Eating Index–2010; aMED, alternate Mediterranean Diet; CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension; HEI-2010, Healthy Eating Index–2010.

[2] Values may appear to overlap due to rounding.

We also investigated each component score separately (adjusting for the total score minus that component score and all other covariates), but it does not appear that any 1 component or diet construct is driving the associations, emphasizing the role overall diet has to play in health outcomes. However, some tension exists between by-component and overall index analyses given our emphasis on the importance of total diet versus the reductionist by-component approach, because without interaction terms, these models assume that components act independently rather than synergistically (43). Future analyses to examine what common components are indicators of a healthy diet and how many constructs may be sufficient to capture or categorize diet quality are warranted.

Other methodologic questions that merit consideration relate to the different principles underlying the scoring systems for each index. For example, what are the trade-offs between the relative simplicity of indices that generate scores on the basis of the given population's median or quintile-based intakes (aMED and DASH) and those with consistent cutoffs (HEI-2010 and AHEI-2010)? Additionally, how do we interpret findings from scores such as the HEI-2010 that incorporate energy adjustment a priori versus those based on absolute values that adjust for energy in the analytic models (AHEI-2010, aMED, and DASH)? As might be expected, higher scores for aMED and DASH were most often associated with higher energy intake (whereas the opposite was true for the HEI-2010). Yet, for all 4 indices, the scores were similarly correlated with other health behaviors and the findings were similar. Additional analyses are needed to elucidate the effects of the scoring metrics themselves.

This analysis is strengthened because it draws on the NIH-AARP Diet and Health Study, a large U.S.-based prospective cohort with comprehensive measures on diet, mortality, and other key variables. Standardizing all steps in the methods and examining all indices within the same cohort, based on the same FFQ, allows for systematic comparisons among the indices. Additionally, findings based on index scores are more readily translated to public health guidelines compared with data-driven methods.

Limitations include the assessment of diet with an FFQ, a tool that is known to contain nondifferential measurement error, although energy adjustment may serve to mitigate some of this error (44,45). Additionally, with only a single measure of diet collected at baseline, we could not account for any changes in intake over time. Little is known about trends in dietary patterns, particularly among older Americans. If intake changed during the 15 y of follow-up, long-term diet quality could be misclassified, another source of potential measurement error. For both of these caveats, it is likely that the true effect size would be underestimated. Plans are underway to further explore the influence of measurement error on the findings and to consider how measurement error may vary across all index components. Another limitation is that the NIH-AARP cohort has a limited number of participants in races and ethnic groups other than white and black non-Hispanic and therefore our findings are not generalizable to the general population. However, the Multiethnic Cohort Study and the Women's Health Initiative include other distinct population subgroups, and if the results from those studies are consistent with ours, it would

TABLE 5 Multivariate HRs (95% CIs) for mortality according to quintiles of diet quality indices for the HEI-2010, AHEI-2010, aMED, and DASH scores among women (n = 182,342) in the NIH-AARP Diet and Health Study[1]

Index and quintile	Range of index score[2]	Women	Any deaths	Follow-up	All-cause mortality	CVD deaths	CVD mortality	Cancer deaths	Cancer mortality
		n	*n*	*person-years*		*n*		*n*	
HEI-2010									
1	18.5–59.3	36,468	8038	500,136	1.00	1987	1.00	2720	1.00
2	59.3–66.1	36,468	6481	508,788	0.88 (0.85, 0.91)	1669	0.90 (0.85, 0.97)	2159	0.89 (0.84, 0.94)
3	66.1–71.3	36,469	6141	509,665	0.88 (0.85, 0.91)	1536	0.87 (0.81, 0.93)	2131	0.92 (0.87, 0.98)
4	71.3–76.4	36,468	5639	513,007	0.82 (0.79, 0.85)	1439	0.82 (0.76, 0.88)	1922	0.85 (0.80, 0.90)
5	76.4–96.2	36,468	5249	514,258	0.77 (0.74, 0.80)	1374	0.79 (0.73, 0.85)	1837	0.82 (0.77, 0.87)
AHEI-2010									
1	17.6–44.7	36,468	7685	502,076	1.00	2000	1.00	2471	1.00
2	44.7–50.1	36,468	6716	506,841	0.91 (0.88, 0.94)	1758	0.91 (0.85, 0.97)	2194	0.93 (0.87, 0.98)
3	50.1–54.9	36,469	6146	510,972	0.85 (0.83, 0.88)	1510	0.81 (0.75, 0.86)	2096	0.90 (0.85, 0.96)
4	54.9–60.7	36,468	5877	511,076	0.85 (0.82, 0.88)	1508	0.84 (0.79, 0.90)	2068	0.92 (0.87, 0.98)
5	60.7–90.7	36,468	5124	514,889	0.76 (0.74, 0.79)	1229	0.72 (0.67, 0.78)	1940	0.88 (0.83, 0.94)
aMED									
1	0–2	32,521	6734	448,047	1.00	1715	1.00	2283	1.00
2	3	32,393	6075	449,339	0.94 (0.90, 0.97)	1525	0.92 (0.86, 0.99)	2022	0.92 (0.87, 0.98)
3	4	37,405	6608	521,867	0.89 (0.86, 0.92)	1675	0.89 (0.83, 0.95)	2274	0.91 (0.86, 0.97)
4	5	35,548	5711	498,601	0.83 (0.80, 0.86)	1416	0.80 (0.75, 0.87)	1929	0.83 (0.78, 0.89)
5	6–9	44,474	6420	627,998	0.76 (0.73, 0.79)	1674	0.78 (0.72, 0.84)	2261	0.79 (0.74, 0.85)
DASH									
1	8–20	38,546	7940	531,826	1.00	2030	1.00	2723	1.00
2	21–22	28,983	5347	402,902	0.93 (0.90, 0.96)	1301	0.88 (0.82, 0.95)	1870	0.97 (0.92, 1.03)
3	23–25	50,032	8378	700,472	0.87 (0.84, 0.89)	2111	0.84 (0.79, 0.89)	2854	0.90 (0.86, 0.95)
4	26–27	29,349	4667	411,943	0.82 (0.79, 0.85)	1184	0.80 (0.74, 0.86)	1551	0.84 (0.78, 0.89)
5	28–37	35,431	5216	498,711	0.78 (0.75, 0.81)	1379	0.78 (0.72, 0.83)	1771	0.82 (0.77, 0.88)

[1] Adjusted for age, race/ethnicity, education, marital status, physical activity, smoking, energy intake, BMI, diabetes, alcohol (HEI-2010 and DASH only), and hormone replacement therapy. AHEI-2010, Alternative Healthy Eating Index–2010; aMED, alternate Mediterranean Diet; CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension; HEI-2010, Healthy Eating Index–2010.
[2] Values may appear to overlap due to rounding.

suggest that our findings are robust. Additionally, because the cohort enrolled participants ≥50 y of age, we cannot rule out survival bias, and thus our findings may be generalizable to older adults only. Last, optimal dietary patterns may also be a marker for overall healthy behaviors that were not completely captured in our study, including access to health care. We cannot rule out the possibility of residual confounding by potential risk factors that were not measured or not fully accounted for in the models.

In summary, our results indicate that following any of these dietary recommendations—federal guidance as operationalized by the HEI-2010, Harvard's Healthy Eating Plate as captured in the AHEI-2010, a Mediterranean diet as adapted in the Americanized aMED, and the DASH Eating Plan as included in the DASH score—is associated with a lower risk of mortality outcomes for men and women. This promising finding suggests that, although there are multiple dietary pattern index scores, their associations with disease tend to converge because they are derived from many of the same core tenets. Although analyses with diet quality indices do not, by definition, pinpoint key nutrients or foods that are protective, this research provides evidence regarding the benefit of an overall healthy eating pattern and suggests the need to optimize the U.S. food environment to support whole grains, vegetables, fruit, and plant-based proteins. Our findings are generalizable to an older U.S. population for both CVD and cancer mortality, and because Americans >65 y old will represent 20% of the population by 2030 (46), public health efforts to improve the diet of Americans are critical. The clear, systematic approach developed in the DPMP allows for comparisons across cohorts and provides a strong foundation for future standardized investigations in cohorts worldwide.

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