

Adherence to the Healthy Eating Index–2015 and Other Dietary Patterns May Reduce Risk of Cardiovascular Disease, Cardiovascular Mortality, and All-Cause Mortality

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ABSTRACT

Background: The Healthy Eating Index–2015 (HEI-2015) score measures adherence to recommendations from the *2015–2020 Dietary Guidelines for Americans*. The HEI-2015 was altered from the HEI-2010 by reclassifying sources of dietary protein and replacing the empty calories component with 2 new components: saturated fats and added sugars.

Objectives: Our aim was to assess whether the HEI-2015 score, along with 3 other previously defined indices, were associated with incident cardiovascular disease (CVD), CVD mortality, and all-cause mortality.

Methods: We conducted a prospective analysis of 12,413 participants aged 45–64 y (56% women) from the Atherosclerosis Risk in Communities (ARIC) Study. The HEI-2015, Alternative Healthy Eating Index–2010 (AHEI-2010), alternate Mediterranean (aMed) diet, and Dietary Approaches to Stop Hypertension Trial (DASH) scores were computed using the average dietary intakes of Visits 1 (1987–1989) and 3 (1993–1995). Incident CVD, CVD mortality, and all-cause mortality data were ascertained from baseline through 31 December, 2017. We used Cox proportional hazards models to estimate HRs and 95% CIs.

Results: There were 4509 cases of incident CVD, 1722 cases of CVD mortality, and 5747 cases of all-cause mortality over a median of 24–25 y of follow-up. Compared with participants in the lowest quintile of HEI-2015, participants in the highest quintile had a 16% lower risk of incident CVD (HR: 0.84; 95% CI: 0.76–0.93; *P*-trend < 0.001), 32% lower risk of CVD mortality (HR: 0.68; 95% CI: 0.58–0.80; *P*-trend < 0.001), and 18% lower risk of all-cause mortality (HR: 0.82; 95% CI: 0.75–0.89; *P*-trend < 0.001) after adjusting for demographic and lifestyle covariates. There were similar protective associations for AHEI-2010, aMed, and DASH scores, and no significant interactions by race.

Conclusions: Higher adherence to the *2015–2020 Dietary Guidelines for Americans* was associated with lower risks of incident CVD, CVD mortality, and all-cause mortality among US adults. *J Nutr* 2020;150:312–321.

Keywords: ARIC, dietary pattern, dietary score, cardiovascular disease, mortality

Introduction

The *2015–2020 Dietary Guidelines for Americans* highlights the importance of healthy eating patterns that represent the totality of foods and beverages habitually consumed, rather than individual dietary components and nutrients that were emphasized in previous editions (1). The components within an eating pattern may have interactive and cumulative health effects and, therefore, eating patterns have the potential to prevent chronic disease to a greater extent than the modification of 1 component (2). The Healthy Eating Index (HEI), which was developed to reflect the *Dietary Guidelines*; the Alternative Healthy Eating Index (AHEI), which consists of dietary components associated with chronic diseases; the alternate Mediterranean (aMed) diet; and the Dietary Approaches to

Stop Hypertension Trial (DASH) diet (3–6) are 4 common indices used in nutrition epidemiology to assess healthy dietary patterns. Although the 4 indices have overlapping components, they each uniquely capture different combinations of food groups and have distinctive scoring methods.

The HEI-2015, based on the most recent *2015–2020 Dietary Guidelines for Americans*, was updated from the HEI-2010 by including legumes in 4 components rather than 2 and splitting the empty calories component (which included solid fats, alcohols, and added sugars) into 2 components: added sugars and saturated fats (3). While previous studies have assessed the associations between earlier versions of the HEI (HEI-2005, HEI-2010) and chronic disease and mortality (4, 7, 8), it is not yet known whether the HEI-2015 is associated

TABLE 1 Baseline characteristics of Atherosclerosis Risk in Communities participants in lowest and highest quintiles of dietary scores¹

Characteristics	HEI-2015		AHEI-2010		aMed		DASH	
	Q1: 60 ²	Q5: 81	Q1: 37	Q5: 67	Q1: 2	Q5: 6	Q1: 18	Q5: 30
<i>n</i>	2483	2482	2483	2482	2381	3071	3094	2398
Age, y	54 ± 6	55 ± 6	53 ± 6	55 ± 6	53 ± 6	54 ± 6	53 ± 6	55 ± 6
Female, %	40	70	49	63	57	55	41	73
Black, %	23	21	28	17	19	24	36	14
Education level, %								
<High school	31	13	29	13	25	16	34	13
High school or equivalent	44	39	43	40	46	38	42	38
≥College	25	47	28	47	29	46	25	49
Annual household income, %								
<\$24,000	40	31	42	30	37	32	45	29
\$24,000–\$49,999	39	38	38	39	40	37	38	39
≥\$50,000	21	32	21	31	23	30	17	32
Smoking status, %								
Never smoker	31	49	40	43	40	45	33	50
Former smoker	29	35	27	37	28	35	29	35
Current smoker	40	15	33	20	32	20	38	15
Alcohol status, %								
Never drinker	19	26	27	21	23	24	24	24
Former drinker	21	16	22	15	20	16	21	16
Current drinker	60	58	51	64	57	60	55	60
Physical activity index score ³	2.3 ± 0.7	2.7 ± 0.8	2.3 ± 0.7	2.7 ± 0.8	2.3 ± 0.8	2.6 ± 0.8	2.2 ± 0.7	2.7 ± 0.8
Total energy intake, kcal/d	1633 ± 602	1330 ± 418	1400 ± 497	1626 ± 479	1312 ± 467	1672 ± 515	1620 ± 562	1403 ± 424

¹Values for categorical variables are given as percentages; for continuous variables, means ± SDs. AHEI, Alternative Healthy Eating Index; aMed, alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension Trial; HEI, Healthy Eating Index; Q, quintile.

²Median score of quintile.

³Physical activity index scores were calculated based on intensity and time of sport and nonsport exercise during leisure time; 1 is lowest and 5 is highest.

with cardiovascular disease (CVD), CVD mortality, or all-cause mortality risks. A study in the Multiethnic Cohort found an inverse association between the HEI-2015 score and all-cause mortality, CVD mortality, and cancer mortality among men and women (9). However, generalizability was limited, as participants were recruited from Hawaii and Los Angeles. Additional studies are needed to confirm these findings in other populations, as well as to examine the association with incident CVD. Previous observational studies have suggested that adhering to healthy dietary patterns may reduce risks of CVD, diabetes, and mortality (4, 7, 10–14).

The primary objective of our analysis was to examine whether the recently published HEI-2015 score is associated

with CVD, CVD mortality, and all-cause mortality risks in the Atherosclerosis Risk in Communities (ARIC) study, a community-based population consisting of black and white participants. We also examined the associations with other dietary pattern indices (AHEI-2010, aMed, and DASH) that are frequently used to assess diet quality and are relevant to dietary guidance in the US population.

Methods

The ARIC study was a community-based, prospective cohort of 15,792 participants, aged 45–64 y at baseline, from 4 US communities (Washington County, Maryland; Forsyth County, North Carolina; Jackson, Mississippi; and Minneapolis suburbs, Minnesota) who were enrolled and examined from 1987 to 1989 (Visit 1) (15). Participants were also seen in person at Visit 2 (1990–1992; *n* = 14,348), Visit 3 (1993–1995; *n* = 12,887), Visit 4 (1996–1998; *n* = 11,656), Visit 5 (2011–2013; *n* = 6538), and Visit 6 (2016–2017; *n* = 4003), and Visit 7 is ongoing. The ARIC study was approved by the Institutional Review Boards of participating institutions, and participants provided written informed consent at each clinical site.

Participants who were neither black nor white (*n* = 48), black from Washington County, Maryland (*n* = 33), and black from Minneapolis, Minnesota (*n* = 22), were excluded from our analysis due to small numbers that did not accurately represent the minority groups within these study centers. Individuals with a history of coronary heart disease (*n* = 763), stroke (*n* = 186), or heart failure (*n* = 594) at baseline were not included. We additionally excluded participants who were missing data on covariates of interest (*n* = 1302), participants with extreme energy intakes (women: <500 or >3500 kcal/d; men: <700 or >4500 kcal/d; *n* = 75), and participants with incomplete FFQs (*n* = 356). Our final study population consisted of 12,413 participants.

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Supplemental Tables 1–8 are available from the “Supplementary data” link in the online posting of the article and from the same link in the online table of contents at <https://academic.oup.com/jn>.

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Abbreviations used: AHEI, Alternative Healthy Eating Index; aMed, alternate Mediterranean diet; ARIC, Atherosclerosis Risk in Communities; CAD, coronary artery disease; CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension Trial; HEI, Healthy Eating Index; ICD, International Classification of Diseases.

TABLE 2 Risks, by quintiles, of Healthy Eating Index among Atherosclerosis Risk in Communities participants¹

	Q1: 60 ² (n = 2483)	Q2: 67 (n = 2483)	Q3: 71 (n = 2482)	Q4: 75 (n = 2483)	Q5: 81 (n = 2482)	P-trend ³
Cardiovascular disease						
Cases, n	1041	913	904	845	806	—
Incidence rate ⁴	22.1	17.8	17.0	15.5	14.5	—
HR (95% CI)	1 (ref.)	0.87 (0.79–0.95)	0.89 (0.81–0.98)	0.84 (0.77–0.93)	0.84 (0.76–0.93)	<0.001
CVD mortality						
Cases, n	425	372	338	309	278	—
Incidence rate ⁴	8.3	7.0	6.2	5.6	5.0	—
HR (95% CI)	1 (ref.)	0.81 (0.71–0.94)	0.75 (0.65–0.87)	0.76 (0.65–0.89)	0.68 (0.58–0.80)	<0.001
All-cause mortality						
Cases, n	1333	1225	1096	1063	1030	—
Incidence rate ⁴	25.7	22.7	19.7	19.0	18.2	—
HR (95% CI)	1 (ref.)	0.90 (0.83–0.97)	0.85 (0.78–0.92)	0.87 (0.80–0.95)	0.82 (0.75–0.89)	<0.001

¹Cox proportional hazards models used to estimate HRs and 95% CIs were adjusted for age, sex, race center (interaction term), total energy intake, education level, income level, physical activity, and smoking status, as well as alcohol status. CVD, cardiovascular disease; Q, quintile; ref., reference.

²Median score of quintile.

³Trend was tested using the median value within each quintile.

⁴Crude incidence rate per 1000 person-years.

Measurement of dietary intake

Dietary intake was assessed using an interviewer-administered, 66-item FFQ that was modified from the 61-item Willett questionnaire and has been validated in ARIC (16–18). The FFQ was administered at Visit 1 (1987–1989) and Visit 3 (1993–1995). Participants were asked by trained interviewers to report the average frequency of consuming food items of a given portion size in the past year. The total energy and nutrient intake was calculated by multiplying the self-reported frequency and portion size of each food item by the nutritional content, using US Department of Agriculture data sources. Cumulative updating of the FFQ by incorporating both Visits 1 and 3 was used to reduce the within-person variation and represent the long-term dietary intake (19). The Visit 1 dietary intake was used for participants who had a CVD event or were censored between Visits 1 and 3, or for those who were missing Visit 3 dietary data. For participants who were censored after Visit 3, we used the mean of their Visit 1 and Visit 3 dietary intakes.

Scoring of dietary patterns

HEI-2015, AHEI-2010, aMed, and DASH diet indices were used to assess adherence to healthy dietary patterns. The HEI-2015 score (ranging from 0–100 possible points) was created to assess adherence to the 2015–2020 US Dietary Guidelines for Americans, and consists of 13 components that were scored based on energy-adjusted food and

nutrient intakes (Supplemental Table 1) (3). The AHEI-2010 score (0–110) was created to include foods, beverages, and nutrients associated with chronic diseases, based on previous literature (Supplemental Table 1) (4). The aMed score (0–9) was developed to assess adherence to a Mediterranean-style diet in the US population (Supplemental Table 1) (5). Due to the narrow range of scores in the aMed diet, as a sensitivity analysis, we modified the scoring using ranked distribution in quintiles for each component except alcohol, which was based on cutoffs (Supplemental Table 2). The range of possible scores for the modified aMed score was 9–45. The DASH score (8–40) was derived by Fung et al. (6) to reflect the DASH dietary pattern, which was tested in 2 randomized, controlled feedings trials (20, 21). The DASH score has 8 components that are each worth 5 points (Supplemental Table 1) (6).

Definition of outcomes

Our primary outcomes were incident CVD, CVD mortality, and all-cause mortality. Incident CVD events were a composite of incident coronary artery disease (CAD), incident stroke, and incident heart failure after Visit 1 through 31 December, 2017. CVD events were ascertained through: 1) annual telephone calls to cohort participants/proxies; 2) active surveillance of local hospital discharge records; 3) state death records; and 4) linkage to the National Death Index (15). Trained abstractors collected data on all CVD-related hospitalizations. CAD

TABLE 3 Risks, by quintiles, of Alternative Healthy Eating Index among Atherosclerosis Risk in Communities participants¹

	Q1: 37 ² (n = 2483)	Q2: 45 (n = 2483)	Q3: 51 (n = 2482)	Q4: 57 (n = 2483)	Q5: 67 (n = 2482)	P-trend ³
Cardiovascular disease						
Cases, n	987	955	860	852	855	—
Incidence rate ⁴	19.9	18.7	16.3	15.9	15.6	—
HR (95% CI)	1 (ref.)	0.96 (0.87–1.05)	0.84 (0.77–0.93)	0.84 (0.77–0.92)	0.85 (0.77–0.93)	<0.001
CVD mortality						
Cases, n	420	346	327	333	296	—
Incidence rate ⁴	8.0	6.5	6.0	6.1	5.3	—
HR (95% CI)	1 (ref.)	0.85 (0.74–0.98)	0.83 (0.72–0.96)	0.78 (0.67–0.90)	0.66 (0.57–0.77)	<0.001
All-cause mortality						
Cases, n	1203	1214	1148	1107	1075	—
Incidence rate ⁴	22.8	22.4	20.9	20.0	19.0	—
HR (95% CI)	1 (ref.)	0.95 (0.88–1.03)	0.92 (0.85–1.00)	0.84 (0.78–0.92)	0.80 (0.73–0.87)	<0.001

¹Cox proportional hazards models used to estimate HRs and 95% CIs were adjusted for age, sex, race center (interaction term), total energy intake, education level, income level, physical activity, and smoking status. CVD, cardiovascular disease; Q, quintile; ref., reference.

²Median score of quintile.

³Trend was tested using the median value within each quintile.

⁴Crude incidence rate per 1000 person-years.

TABLE 4 Risks, by quintiles, of alternate Mediterranean diet among Atherosclerosis Risk in Communities participants¹

	Q1: 2 ² (n = 2381)	Q2: 3 (n = 2216)	Q3: 4 (n = 2501)	Q4: 5 (n = 2244)	Q5: 6 (n = 3071)	P-trend ³
Cardiovascular disease						
Cases, n	892	809	927	813	1068	—
Incidence rate ⁴	18.2	17.6	17.7	17.1	15.9	—
HR (95% CI)	1 (ref.)	0.93 (0.84–1.02)	0.94 (0.86–1.03)	0.91 (0.82–1.00)	0.84 (0.77–0.93)	<0.001
CVD mortality						
Cases, n	353	330	342	308	389	—
Incidence rate ⁴	6.9	6.9	6.3	6.3	5.6	—
HR (95% CI)	1 (ref.)	0.94 (0.81–1.09)	0.86 (0.74–0.99)	0.77 (0.66–0.91)	0.66 (0.57–0.77)	<0.001
All-cause mortality						
Cases, n	1123	1046	1191	1040	1347	—
Incidence rate ⁴	21.8	21.7	21.7	20.8	19.3	—
HR (95% CI)	1 (ref.)	0.93 (0.86–1.01)	0.93 (0.86–1.01)	0.84 (0.77–0.91)	0.76 (0.70–0.83)	<0.001

¹ Cox proportional hazards models used to estimate HRs and 95% CIs were adjusted for age, sex, race center (interaction term), total energy intake, education level, income level, physical activity, and smoking status. CVD, cardiovascular disease; Q, quintile; ref., reference.

² Median score of quintile.

³ Trend was tested using the median value within each quintile.

⁴ Crude incidence rate per 1000 person-years.

events were defined as a definite or probable myocardial infarction, fatal CAD by a physician review, or coronary revascularization (22). Definite or probable incident stroke was classified by physician reviewers and a computer algorithm, using criteria adapted from the National Survey of Stroke. Stroke was defined as a sudden neurologic insult of ≥ 24 -h duration or a neurologic insult associated with death without evidence of a nonstroke cause of death. Heart failure was defined by a hospitalization or death with an International Classification of Diseases (ICD)-9 code 428 or ICD-10 code I50.

CVD mortality was defined as a death with CVD as the underlying cause (ICD-9 codes 390–459 or ICD-10 codes I00–I99). All-cause mortality was defined as any death subsequent to Visit 1 until the end of 2017, as determined by annual telephone calls, linkage to local hospital and state health department records, and linkage to the National Death Index.

Covariates

A questionnaire was administered to participants at baseline by trained interviewers to ascertain age, sex, race, education level, income level, physical activity [sport and nonsport exercise activity during leisure, from the Baecke questionnaire (23, 24)], smoking

status, alcohol status, and medical history. Race and center were combined into a single variable (race center interaction term) given the nonuniform distribution of racial groups across centers. Education levels were categorized as less than high school, high school or equivalent, and college or higher. Income levels were categorized as an annual household income <\$24,000, \$24,000–49,999, and \geq \$50,000. Smoking status and alcohol status were categorized as never, former, and current.

Statistical analysis

We summarized baseline characteristics of participants by quintiles of each dietary score. Differences in baseline characteristics by each score were assessed using the χ^2 test and ANOVA. The correlations between dietary scores were calculated using Pearson's correlation. We used Cox proportional hazards regression models to calculate HRs and 95% CIs, to quantify the association between each dietary score and risks of CVD, CVD mortality, and all-cause mortality. We adjusted the analyses for potential confounders: age, sex, race center (interaction term), total energy intake, education level, income level, physical activity, and smoking status. Alcohol status was also adjusted for in analyses using HEI-2015 and DASH scores, because alcohol was not scored in those

TABLE 5 Risks, by quintiles, of Dietary Approaches to Stop Hypertension Trial among Atherosclerosis Risk in Communities participants¹

	Q1: 18 ² (n = 3094)	Q2: 22 (n = 2447)	Q3: 25 (n = 2791)	Q4: 27 (n = 1683)	Q5: 30 (n = 2398)	P-trend ³
Cardiovascular disease						
Cases, n	1248	908	998	602	753	—
Incidence rate ⁴	20.7	17.8	16.6	16.6	13.9	—
HR (95% CI)	1 (ref.)	0.97 (0.89–1.05)	0.99 (0.91–1.08)	1.00 (0.90–1.11)	0.89 (0.81–0.99)	0.1
CVD mortality						
Cases, n	534	336	357	211	284	—
Incidence rate ⁴	8.3	6.4	5.8	5.6	5.2	—
HR (95% CI)	1 (ref.)	0.90 (0.78–1.03)	0.91 (0.79–1.05)	0.91 (0.77–1.07)	0.79 (0.68–0.93)	0.01
All-cause mortality						
Cases, n	1637	1156	1221	729	1004	—
Incidence rate ⁴	25.0	21.6	19.5	19.3	18.3	—
HR (95% CI)	1 (ref.)	0.94 (0.87–1.02)	0.96 (0.88–1.03)	0.93 (0.85–1.02)	0.88 (0.80–0.96)	0.01

¹ Cox proportional hazards models used to estimate HRs and 95% CIs were adjusted for age, sex, race center (interaction term), total energy intake, education level, income level, physical activity, and smoking status, as well as alcohol status. CVD, cardiovascular disease; Q, quintile; ref., reference.

² Median score of quintile.

³ Trend was tested using the median value within each quintile.

⁴ Crude incidence rate per 1000 person-years.

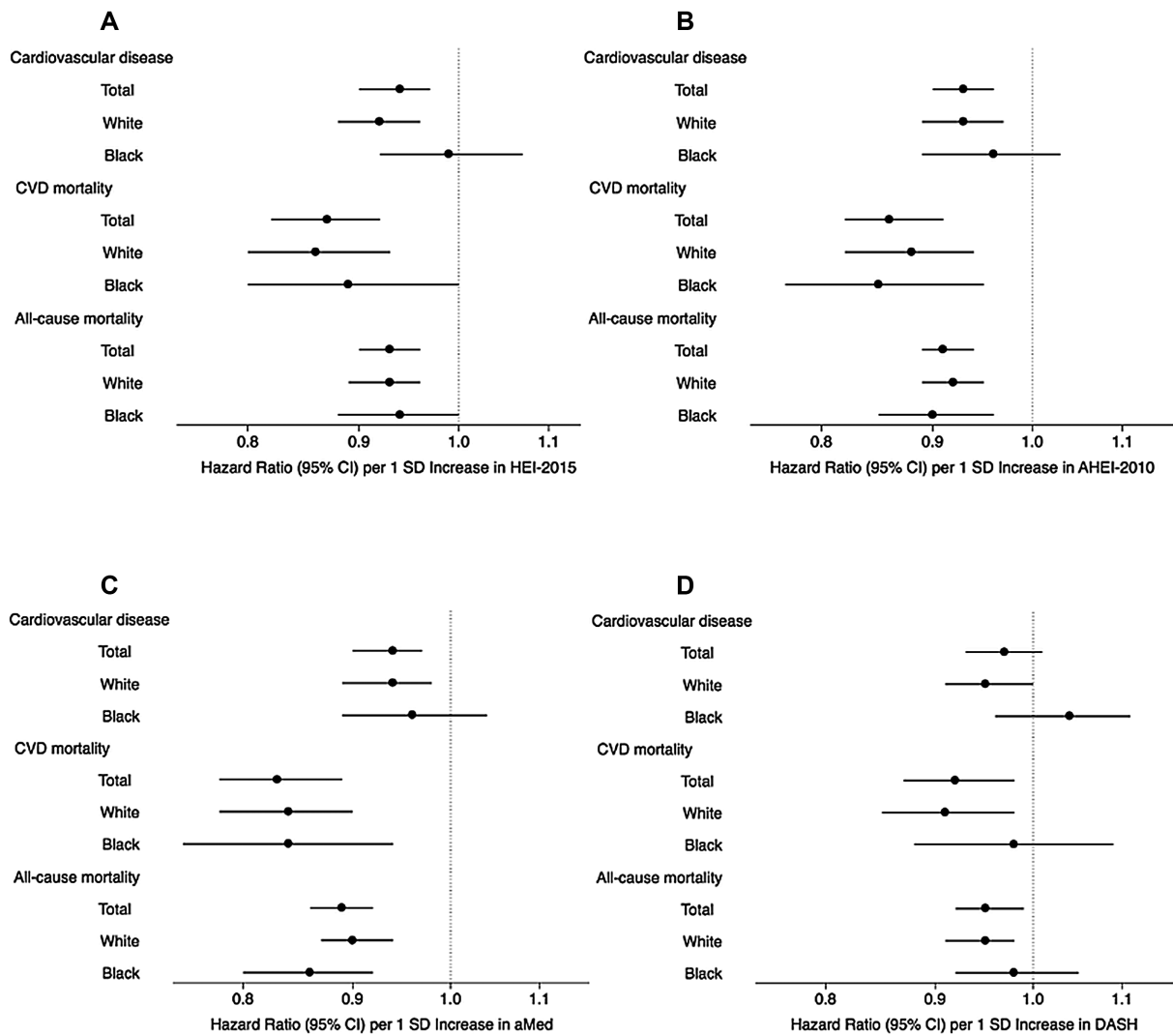


FIGURE 1 HRs (on logarithmic scale) of CVD, CVD mortality, and all-cause mortality per 1 SD increase of each dietary score among ARIC participants, stratified by race. (A) HEI-2015; (B) AHEI-2010; (C) aMed; and (D) DASH. SD for HEI-2015 = 8.3; AHEI-2010 = 11.8; aMed = 1.8; and DASH = 4.9. Cox proportional hazards models to estimate HRs and 95% CIs were adjusted for age, sex, race center (interaction term), total energy intake, education level, income level, physical activity, and smoking status. HEI-2015 and DASH scores were additionally adjusted for alcohol status. AHEI, Alternative Healthy Eating Index; aMed, alternate Mediterranean diet; ARIC, Atherosclerosis Risk in Communities; CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension Trial; HEI, Healthy Eating Index.

indices. We calculated *P*-trends using the median value of each quintile of a dietary score. HRs were calculated by quintiles of each dietary score and for each SD increase in a dietary score. We also conducted stratified analyses by race for each dietary score and tested for interactions using the likelihood ratio test. All analyses were performed using Stata (version 14.0; StataCorp).

Results

Participant characteristics

Baseline characteristics of the study population, according to lowest and highest quintiles of each dietary score, are shown in [Table 1](#). Characteristics, by quintile, of each score are shown in [Supplemental Tables 3–6](#). With respect to demographic and lifestyle characteristics, participants who had higher dietary scores were more likely to be female, have at least a college degree, have a higher income, never smoke, and be more

physically active, compared to their counterparts with lower scores ([Table 1](#)). [Supplemental Table 7](#) shows the mean consumption of individual HEI-2015 components, according to quintile. The correlation between dietary scores ranged from 0.59 (HEI-2015 and aMed) to 0.79 (HEI-2015 and DASH).

Dietary patterns and risks

During a median follow-up time of 24 y, 4509 cases of incident CVD occurred. After adjustment for age, sex, race center, total energy intake, education level, income level, physical activity, smoking status, and alcohol status, participants in the highest quintile of HEI-2015 had a 16% (HR: 0.84; 95% CI: 0.76–0.93) lower risk of incident CVD, compared to participants in quintile 1 ([Tables 2–5](#)). Participants in the highest quintiles of AHEI-2010, aMed, and DASH had, respectively, 15% (HR: 0.85; 95% CI: 0.77–0.93), 16% (HR: 0.84; 95% CI: 0.77–0.93), and 11% (HR: 0.89; 95% CI: 0.81–0.99) lower risks of CVD, compared to participants in the lowest quintiles. For

TABLE 6 Risks, by quintiles, of Healthy Eating Index among white Atherosclerosis Risk in Communities participants¹

	Q1: 60 ² (n = 1914)	Q2: 67 (n = 1835)	Q3: 71 (n = 1822)	Q4: 75 (n = 1939)	Q5: 81 (n = 1963)	P-trend ³
Cardiovascular disease						
Cases, n	794	667	639	625	602	—
Incidence rate ⁴	21.3	17.3	16.1	14.5	13.5	—
HR (95% CI)	1 (ref.)	0.89 (0.80–0.99)	0.88 (0.79–0.98)	0.82 (0.74–0.92)	0.82 (0.73–0.92)	<0.001
CVD mortality						
Cases, n	293	244	219	208	196	—
Incidence rate ⁴	7.3	6.1	5.4	4.7	4.4	—
HR (95% CI)	1 (ref.)	0.82 (0.69–0.98)	0.76 (0.63–0.91)	0.79 (0.66–0.96)	0.66 (0.54–0.81)	<0.001
All-cause mortality						
Cases, n	994	870	763	801	792	—
Incidence rate ⁴	24.3	21.5	18.4	18.0	17.5	—
HR (95% CI)	1 (ref.)	0.92 (0.84–1.01)	0.85 (0.77–0.94)	0.89 (0.81–0.98)	0.81 (0.74–0.90)	<0.001

¹ Cox proportional hazards models to estimate HRs and 95% CIs were adjusted for age, sex, center, total energy intake, education level, income level, physical activity, and smoking status, as well as alcohol status. CVD, cardiovascular disease; Q, quintile; ref., reference.

² Median score of quintile.

³ Trend was tested using the median value within each quintile.

⁴ Crude incidence rate per 1000 person-years.

each additional increase in the SD of a dietary score, the risk of CVD was reduced by 3–7% (Figure 1).

There were 1722 deaths due to CVD during a median follow-up of 25 y. After adjustment for covariates, participants in the highest quintiles of HEI-2015, AHEI-2010, aMed, and DASH scores had, respectively, 32% (HR: 0.68; 95% CI: 0.58–0.80), 34% (HR: 0.66; 95% CI: 0.57–0.77), 34% (HR: 0.66; 95% CI: 0.57–0.77), and 21% (HR: 0.79; 95% CI: 0.68–0.93) lower risks of CVD mortality (Tables 2–5). Each additional increase in the SD of a dietary score reduced the risk of CVD mortality by 8–17% (Figure 1).

We documented 5747 deaths due to any cause over a median follow-up time of 25 y. The highest quintiles of HEI-2015, AHEI-2010, aMed, and DASH scores were, respectively, associated with 18% (HR: 0.82; 95% CI: 0.75–0.89), 20%

(HR: 0.80; 95% CI: 0.73–0.87), 24% (HR: 0.76; 95% CI: 0.70–0.83), and 12% (HR: 0.88; 95% CI: 0.80–0.96) lower risks of all-cause mortality, after adjustment for covariates (Tables 2–5). Each additional SD increase in a dietary score was associated with a 4–11% lower risk of all-cause mortality (Figure 1).

Sensitivity analyses

When we stratified our analyses by race, we found similar relative measures of association between white and black participants (*P*-interactions > 0.05; Tables 6–13). The estimates for whites were similar to the estimates for the total population (Tables 6–9). However, for black participants, none of the dietary patterns were associated with CVD (Tables 10–13; Figure 1). Among black participants, the AHEI-2010 and aMed were associated with reduced risks of CVD mortality and all-

TABLE 7 Risks, by quintiles, of Alternative Healthy Eating Index among white Atherosclerosis Risk in Communities participants¹

	Q1: 37 ² (n = 1800)	Q2: 45 (n = 1817)	Q3: 51 (n = 1886)	Q4: 57 (n = 1906)	Q5: 67 (n = 2064)	P-trend ³
Cardiovascular disease						
Cases, n	700	665	632	638	692	—
Incidence rate ⁴	18.9	17.5	15.5	15.4	15.0	—
HR (95% CI)	1 (ref.)	0.95 (0.86–1.06)	0.84 (0.75–0.94)	0.85 (0.76–0.95)	0.84 (0.75–0.93)	<0.001
CVD mortality						
Cases, n	256	210	232	226	236	—
Incidence rate ⁴	6.6	5.3	5.5	5.3	5.0	—
HR (95% CI)	1 (ref.)	0.85 (0.70–1.02)	0.90 (0.75–1.08)	0.83 (0.69–1.00)	0.68 (0.56–0.82)	<0.001
All-cause mortality						
Cases, n	812	863	844	826	875	—
Incidence rate ⁴	20.6	21.4	19.9	19.2	18.4	—
HR (95% CI)	1 (ref.)	1.01 (0.91–1.11)	0.96 (0.87–1.06)	0.89 (0.81–0.98)	0.82 (0.74–0.90)	<0.001

¹ Cox proportional hazards models to estimate HRs and 95% CIs were adjusted for age, sex, center, total energy intake, education level, income level, physical activity, and smoking status. CVD, cardiovascular disease; Q, quintile; ref., reference.

² Median score of quintile.

³ Trend was tested using the median value within each quintile.

⁴ Crude incidence rate per 1000 person-years.

TABLE 8 Risks, by quintiles, of alternate Mediterranean diet among white Atherosclerosis Risk in Communities participants¹

	Q1: 2 ² (n = 1926)	Q2: 3 (n = 1678)	Q3: 4 (n = 1887)	Q4: 5 (n = 1655)	Q5: 6 (n = 2327)	P-trend ³
Cardiovascular disease						
Cases, n	711	588	676	578	774	—
Incidence rate ⁴	17.6	16.4	16.8	16.3	15.1	—
HR (95% CI)	1 (ref.)	0.90 (0.81–1.01)	0.93 (0.84–1.04)	0.91 (0.82–1.02)	0.83 (0.74–0.92)	<0.001
CVD mortality						
Cases, n	247	210	237	198	268	—
Incidence rate ⁴	5.9	5.7	5.7	5.4	5.1	—
HR (95% CI)	1 (ref.)	0.87 (0.72–1.05)	0.92 (0.77–1.11)	0.79 (0.65–0.95)	0.65 (0.54–0.78)	<0.001
All-cause mortality						
Cases, n	876	744	855	740	1005	—
Incidence rate ⁴	20.7	19.9	20.3	19.8	18.8	—
HR (95% CI)	1 (ref.)	0.88 (0.80–0.98)	0.93 (0.84–1.02)	0.84 (0.76–0.93)	0.77 (0.70–0.85)	<0.001

¹Cox proportional hazards models to estimate HRs and 95% CIs were adjusted for age, sex, center, total energy intake, education level, income level, physical activity, and smoking status. CVD, cardiovascular disease; Q, quintile; ref., reference.

²Median score of quintile.

³Trend was tested using the median value within each quintile.

⁴Crude incidence rate per 1000 person-years.

cause mortality, and the DASH score was not significantly associated with any of the outcomes.

In our sensitivity analysis, using a modified version of the aMed score for a wider distribution of scores, results were similar to the original aMed scoring (Supplemental Table 8).

Discussion

In our analysis of 12,413 participants from the ARIC study, we observed inverse associations for the HEI-2015 score and incident CVD, CVD mortality, and all-cause mortality. Findings for the AHEI-2010 and aMed were generally consistent and DASH was slightly weaker but still consistent, compared to the HEI-2015. The strongest associations were observed for CVD mortality, in which the highest adherence (quintile 5) to the healthy dietary patterns were associated with 21–34% reductions in risk, compared to participants with the lowest adherence (quintile 1). Participants in quintile 5 had 11–16%

reduced risks for incident CVD and 12–24% reduced risks of all-cause mortality, compared to participants in quintile 1. Results were significant for almost all quintiles, suggesting that even small improvements in diet quality may reduce risks of CVD and mortality.

Our results were consistent with previous studies that reported inverse associations between healthy dietary patterns and CVD, CVD mortality, and all-cause mortality (7, 12). The Dietary Patterns Methods Project used a standardized approach to synthesize findings from 3 cohorts (NIH-American Association of Retired Persons Diet and Health Study, the Multiethnic Cohort, and the Women's Health Initiative Observational Study) to assess the associations between HEI-2010, AHEI-2010, aMed, and DASH scores and risks of CVD mortality, cancer mortality, and all-cause mortality (7). The authors observed 11–28% reductions in risks of death from all causes, CVD, and cancer when comparing the highest quintile of dietary scores to the lowest quintile, after adjusting for similar confounders as those used in our study (7). Other studies

TABLE 9 Risks, by quintiles, of Dietary Approaches to Stop Hypertension Trial among white Atherosclerosis Risk in Communities participants¹

	Q1: 18 ² (n = 1973)	Q2: 22 (n = 1828)	Q3: 25 (n = 2213)	Q4: 27 (n = 1390)	Q5: 31 (n = 2069)	P-trend ³
Cardiovascular disease						
Cases, n	792	663	758	481	633	—
Incidence rate ⁴	20.2	17.2	15.8	15.9	13.4	—
HR (95% CI)	1 (ref.)	0.93 (0.84–1.03)	0.94 (0.85–1.04)	0.96 (0.85–1.08)	0.86 (0.77–0.97)	0.03
CVD mortality						
Cases, n	295	225	245	160	235	—
Incidence rate ⁴	7.0	5.6	5.0	5.1	5.0	—
HR (95% CI)	1 (ref.)	0.86 (0.72–1.02)	0.85 (0.72–1.02)	0.87 (0.71–1.06)	0.78 (0.64–0.94)	0.01
All-cause mortality						
Cases, n	996	837	944	591	852	—
Incidence rate ⁴	23.4	20.6	18.8	18.8	17.8	—
HR (95% CI)	1 (ref.)	0.91 (0.83–1.00)	0.93 (0.85–1.02)	0.91 (0.81–1.01)	0.86 (0.77–0.95)	0.01

¹Cox proportional hazards models to estimate HRs and 95% CIs were adjusted for age, sex, center, total energy intake, education level, income level, physical activity, and smoking status, as well as alcohol status. CVD, cardiovascular disease; Q, quintile; ref., reference.

²Median score of quintile.

³Trend was tested using the median value within each quintile.

⁴Crude incidence rate per 1000 person-years.

TABLE 10 Risks, by quintiles, of Healthy Eating Index among black Atherosclerosis Risk in Communities participants¹

	Q1: 60 ² (n = 569)	Q2: 67 (n = 648)	Q3: 71 (n = 660)	Q4: 75 (n = 544)	Q5: 81 (n = 519)	P-trend ³
Cardiovascular disease						
Cases, n	247	246	265	220	204	—
Incidence rate ⁴	24.9	19.1	19.4	19.5	18.6	—
HR (95% CI)	1 (ref.)	0.81 (0.68–0.97)	0.90 (0.76–1.08)	0.93 (0.77–1.12)	0.94 (0.77–1.15)	0.9
CVD mortality						
Cases, n	132	128	119	101	82	—
Incidence rate ⁴	12.2	9.6	8.5	8.8	7.3	—
HR (95% CI)	1 (ref.)	0.80 (0.62–1.02)	0.74 (0.57–0.95)	0.75 (0.58–0.99)	0.76 (0.57–1.02)	0.04
All-cause mortality						
Cases, n	339	355	333	262	238	—
Incidence rate ⁴	30.9	26.3	23.6	22.5	20.9	—
HR (95% CI)	1 (ref.)	0.84 (0.73–0.98)	0.83 (0.71–0.97)	0.83 (0.70–0.98)	0.85 (0.71–1.01)	0.05

¹ Cox proportional hazards models to estimate HRs and 95% CIs were adjusted for age, sex, center, total energy intake, education level, income level, physical activity, and smoking status, as well as alcohol status. CVD, cardiovascular disease; Q, quintile; ref., reference.

² Median score of quintile.

³ Trend was tested using the median value within each quintile.

⁴ Crude incidence rate per 1000 person-years.

have found similar protective findings for cardiovascular events and total and cardiovascular mortality with the HEI (4, 8), AHEI (4, 8, 25), Mediterranean diet (13, 26), and DASH diet (6, 8) indices. The majority of these studies were conducted in Caucasian cohorts; therefore, generalizability was limited and it was unclear whether the associations were replicable among black participants. Our analysis in ARIC found that the associations between HEI-2015 scores and incident CVD, CVD mortality, and all-cause mortality were similar in direction and magnitude for white and black participants, and there were no significant interactions. However, there were no significant associations between dietary scores and CVD among black participants. This may be due to the small sample size of black participants (24% of the entire study population).

Although some of these scores have been previously examined, a novel aspect of this study was the use of the HEI-2015 index, which was updated from the HEI-2010 with the release of the 2015–2020 *Dietary Guidelines for Americans*. The HEI-2015 differs from the previous version by including legumes in the scoring of 4 components (total vegetables, greens

and beans, total protein, and seafood and plant protein) rather than 2 and separating the empty calories (solid fats, alcohols, and added sugars) component into 2 separate components (saturated fats and added sugars) (3). To date, 1 study in the Multiethnic Cohort has examined the associations between the HEI-2015 and all-cause, CVD, and cancer mortality, and found inverse associations similar to those found in our study (9). In their study, they found that the risk of all-cause mortality was 21% lower (HR for quintile 5 compared with 1: 0.79; 95% CI: 0.76–0.82) for both men and women and the risks of CVD mortality were 24% lower (HR: 0.76; 95% CI: 0.71–0.82) for men and 25% lower (HR: 0.75; 95% CI: 0.70–0.81) for women (9). In our study, we also found a stronger association between healthy diet and CVD mortality, compared to all-cause mortality.

In the present study, all 4 indices performed similarly with regards to risks of incident CVD, CVD mortality, and all-cause mortality, suggesting that each of these healthy dietary patterns can be recommended and incorporated into healthy lifestyles, despite some differences in scoring criteria. There are some

TABLE 11 Risks, by quintiles, of Alternative Healthy Eating Index among black Atherosclerosis Risk in Communities participants¹

	Q1: 37 ² (n = 683)	Q2: 45 (n = 666)	Q3: 51 (n = 596)	Q4: 57 (n = 577)	Q5: 66 (n = 418)	P-trend ³
Cardiovascular disease						
Cases, n	287	290	228	214	163	—
Incidence rate ⁴	22.8	22.2	18.9	17.6	18.5	—
HR (95% CI)	1 (ref.)	0.99 (0.84–1.16)	0.88 (0.74–1.05)	0.86 (0.72–1.03)	0.96 (0.78–1.18)	0.3
CVD mortality						
Cases, n	164	136	95	107	60	—
Incidence rate ⁴	12.3	9.9	7.7	8.6	6.6	—
HR (95% CI)	1 (ref.)	0.87 (0.69–1.09)	0.74 (0.57–0.96)	0.75 (0.58–0.96)	0.68 (0.50–0.92)	<0.001
All-cause mortality						
Cases, n	391	351	304	281	200	—
Incidence rate ⁴	29.1	25.3	24.3	22.4	21.8	—
HR (95% CI)	1 (ref.)	0.85 (0.73–0.98)	0.85 (0.73–0.99)	0.76 (0.65–0.89)	0.79 (0.66–0.94)	<0.001

¹ Cox proportional hazards models to estimate HRs and 95% CIs were adjusted for age, sex, center, total energy intake, education level, income level, physical activity, and smoking status. CVD, cardiovascular disease; Q, quintile; ref., reference.

² Median score of quintile.

³ Trend was tested using the median value within each quintile.

⁴ Crude incidence rate per 1000 person-years.

TABLE 12 Risks, by quintiles, of alternate Mediterranean diet among black Atherosclerosis Risk in Communities participants¹

	Q1: 2 ² (n = 455)	Q2: 3 (n = 538)	Q3: 4 (n = 614)	Q4: 5 (n = 589)	Q5: 6 (n = 744)	P-trend ³
Cardiovascular disease						
Cases, n	181	221	251	235	294	—
Incidence rate ⁴	21.1	21.9	20.7	19.5	18.6	—
HR (95% CI)	1 (ref.)	1.03 (0.85–1.26)	0.98 (0.71–1.19)	0.94 (0.77–1.15)	0.95 (0.78–1.15)	0.4
CVD mortality						
Cases, n	106	120	105	110	121	—
Incidence rate ⁴	11.6	11.3	8.3	8.9	7.5	—
HR (95% CI)	1 (ref.)	1.05 (0.81–1.37)	0.74 (0.56–0.97)	0.79 (0.60–1.05)	0.72 (0.54–0.95)	<0.001
All-cause mortality						
Cases, n	247	302	336	300	342	—
Incidence rate ⁴	26.8	28.3	26.4	23.9	20.8	—
HR (95% CI)	1 (ref.)	1.06 (0.90–1.26)	0.93 (0.79–1.10)	0.84 (0.71–1.00)	0.75 (0.63–0.90)	<0.001

¹Cox proportional hazards models to estimate HRs and 95% CIs were adjusted for age, sex, center, total energy intake, education level, income level, physical activity, and smoking status. CVD, cardiovascular disease; Q, quintile; ref., reference.

²Median score of quintile.

³Trend was tested using the median value within each quintile.

⁴Crude incidence rate per 1000 person-years.

similarities and differences worth highlighting. All 4 indices included vegetables, fruits, and whole grains. Components that were unique to the HEI-2015 included refined grains, all dairy, the unsaturated/saturated fat ratio, saturated fats, and added sugars. Component groups that were not defined as 1 of the 13 groups in the HEI-2015 but were, to a variable extent, in the other 3 scores included low-fat dairy, sugar-sweetened beverages, nuts and legumes, red/processed meat, fish, trans fat, long-chain fats, polyunsaturated fats, and alcohol. Additionally, some food items contributed to multiple components; for example, whole fruits were counted in 2 components (total fruits and whole fruits) and beans were counted in 4 components (total vegetables, greens and beans, total protein, and seafood and plant proteins).

Along with the previous literature, our findings confirm the legitimacy of using dietary patterns as a holistic measure of overall dietary intake and highlight the importance of national dietary guidelines. Although the HEI-2015 appeared to have the strongest associations with the outcomes of all 4 dietary

indices assessed, the differences among HRs between indices were marginal and, therefore, we cannot conclude that the HEI-2015 is superior in that regard. However, the HEI index may be considered a strong index, because it is constantly being improved upon with each update of the Dietary Guidelines, as our scientific knowledge and understanding of diets and health are cumulating.

A limitation of this study was self-reported dietary intakes, which may have resulted in measurement errors. However, the FFQs were administered in person by trained interviewers. Furthermore, we used a cumulative average approach to make use of 2 FFQs that were administered ~6 y apart, when available, in order to use a more precise estimate of diet. Another limitation is that, although food intakes were most likely correctly ranked because of the nature of the FFQ, nutrient intakes were most likely underestimated. Despite adjusting for many covariates that were potential confounders, it is possible that there was still residual confounding. Associations between individual components of the scores were not examined in this

TABLE 13 Risks, by quintiles, of Dietary Approaches to Stop Hypertension Trial among black Atherosclerosis Risk in Communities participants¹

	Q1: 18 ² (n = 1121)	Q2: 22 (n = 619)	Q3: 25 (n = 578)	Q4: 27 (n = 293)	Q5: 30 (n = 329)	P-trend ³
Cardiovascular disease						
Cases, n	456	245	240	121	120	—
Incidence rate ⁴	21.6	19.8	19.7	20.0	17.3	—
HR (95% CI)	1 (ref.)	1.03 (0.88–1.20)	1.12 (0.85–1.32)	1.15 (0.93–1.41)	1.01 (0.82–1.25)	0.3
CVD mortality						
Cases, n	239	111	112	51	49	—
Incidence rate ⁴	10.6	8.7	9.0	8.2	6.9	—
HR (95% CI)	1 (ref.)	1.00 (0.79–1.25)	1.06 (0.84–1.33)	1.02 (0.74–1.39)	0.87 (0.63–1.20)	0.7
All-cause mortality						
Cases, n	641	319	277	138	152	—
Incidence rate ⁴	28.2	24.8	22.2	21.8	21.2	—
HR (95% CI)	1 (ref.)	1.00 (0.88–1.15)	1.00 (0.87–1.16)	1.01 (0.83–1.22)	0.93 (0.77–1.12)	0.6

¹Cox proportional hazards models to estimate HRs and 95% CIs were adjusted for age, sex, center, total energy intake, education level, income level, physical activity, and smoking status, as well as alcohol status. CVD, cardiovascular disease; Q, quintile; ref., reference.

²Median score of quintile.

³Trend was tested using the median value within each quintile.

⁴Crude incidence rate per 1000 person-years.

analysis, given our focus on a holistic measure of diet that accounts for potential interactions between components. Our findings suggest that there are different ways to define a healthy dietary pattern, and they may each have similar effects on clinical outcomes.

There were several strengths in our study, including the use of trained interviewers to administer the FFQ, a prospective design, a relatively long follow-up period, rigorous ascertainment of CVD morbidity and mortality through active ascertainment and linkage to death records, and a large cohort with sufficient power to detect statistically significant associations.

In conclusion, we found that a higher diet quality, characterized by the HEI-2015 and 3 other dietary indices, was associated with reduced risks of incident CVD, CVD mortality, and all-cause mortality in a prospective cohort of 12,413 black and white adults. Our findings add evidence to the protective associations between the HEI-2015 score and cardiovascular and death outcomes, as well as corroborate previous literature on the AHEI-2010, aMed, and DASH scores.

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