

# Healthy Eating Patterns and Risk of Total and Cause-Specific Mortality

Zhilei Shan, MD, PhD; Fenglei Wang, PhD; Yanping Li, MD, PhD; Megu Y. Baden, MD, PhD; Shilpa N. Bhupathiraju, PhD; Dong D. Wang, MD, ScD; Qi Sun, MD, ScD; Kathryn M. Rexrode, MD, MPH; Eric B. Rimm, ScD; Lu Qi, MD, PhD; Fred K. Tabung, PhD; Edward L. Giovannucci, PhD; Walter C. Willett, MD, DrPH; JoAnn E. Manson, MD, DrPH; Qibin Qi, PhD; Frank B. Hu, MD, PhD

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**IMPORTANCE** The current Dietary Guidelines for Americans recommend multiple healthy eating patterns. However, few studies have examined the associations of adherence to different dietary patterns with long-term risk of total and cause-specific mortality.

**OBJECTIVE** To examine the associations of dietary scores for 4 healthy eating patterns with risk of total and cause-specific mortality.

**DESIGN, SETTING, AND PARTICIPANTS** This prospective cohort study included initially healthy women from the Nurses' Health Study (NHS; 1984-2020) and men from the Health Professionals Follow-up Study (HPFS; 1986-2020).

**EXPOSURES** Healthy Eating Index 2015 (HEI-2015), Alternate Mediterranean Diet (AMED) score, Healthful Plant-based Diet Index (HPDI), and Alternate Healthy Eating Index (AHEI).

**MAIN OUTCOMES AND MEASURES** The main outcomes were total and cause-specific mortality overall and stratified by race and ethnicity and other potential risk factors.

**RESULTS** The final study sample included 75 230 women from the NHS (mean [SD] baseline age, 50.2 [7.2] years) and 44 085 men from the HPFS (mean [SD] baseline age, 53.3 [9.6] years). During a total of 3 559 056 person-years of follow-up, 31 263 women and 22 900 men died. When comparing the highest with the lowest quintiles, the pooled multivariable-adjusted HRs of total mortality were 0.81 (95% CI, 0.79-0.84) for HEI-2015, 0.82 (95% CI, 0.79-0.84) for AMED score, 0.86 (95% CI, 0.83-0.89) for HPDI, and 0.80 (95% CI, 0.77-0.82) for AHEI ( $P < .001$  for trend for all). All dietary scores were significantly inversely associated with death from cardiovascular disease, cancer, and respiratory disease. The AMED score and AHEI were inversely associated with mortality from neurodegenerative disease. The inverse associations between these scores and risk of mortality were consistent in different racial and ethnic groups, including Hispanic, non-Hispanic Black, and non-Hispanic White individuals.

**CONCLUSIONS AND RELEVANCE** In this cohort study of 2 large prospective cohorts with up to 36 years of follow-up, greater adherence to various healthy eating patterns was consistently associated with lower risk of total and cause-specific mortality. These findings support the recommendations of Dietary Guidelines for Americans that multiple healthy eating patterns can be adapted to individual food traditions and preferences.

JAMA Intern Med. doi:10.1001/jamainternmed.2022.6117  
Published online January 9, 2023.

**Author Affiliations:** Author affiliations are listed at the end of this article.

**Corresponding Author:** Frank B. Hu, MD, PhD, Department of Nutrition, Harvard T.H. Chan School of Public Health, 665 Huntington Ave, Boston, MA 02115 ([frank.hu@channing.harvard.edu](mailto:frank.hu@channing.harvard.edu)).

Diet remains a cornerstone for maintaining optimal health.<sup>1</sup> According to the Global Burden of Disease Study 2017,<sup>2</sup> unhealthy diet is estimated as one of the leading causes of death globally. The supportive evidence was largely based on nutrition research focusing on single nutrients or foods in relation to total and cause-specific mortality.<sup>2-7</sup> However, humans do not consume isolated nutrients or single foods but rather a wide variety of foods with combinations of nutrients and phytochemicals that may have additive and synergistic effects.<sup>8</sup> By accounting for potentially interactive and cumulative effects among different dietary components, overall dietary patterns have been emphasized as a crucial approach when investigating the association between human diet and health outcomes.<sup>9,10</sup>

Following the evolution in nutritional sciences, the Dietary Guidelines for Americans (DGAs) shifted their focus from individual nutrients to healthy eating patterns in 2010 and have recommended various healthy eating patterns.<sup>11</sup> These recommendations were carried forward to the 2020 to 2025 edition and further highlighted across the lifespan, from birth through older adulthood.<sup>12</sup> However, few long-term prospective studies with repeated dietary measurements have systematically examined whether adherence to various dietary patterns renders similar associations with total and cause-specific mortality.<sup>13-15</sup> Additionally, these recommended eating patterns were intended for all US individuals, but previous evidence indicated notable differences within dietary patterns by individuals' characteristics.<sup>16,17</sup>

Therefore, using 2 large prospective cohorts with data on repeated measures of dietary habits, we derived dietary scores for 4 healthy dietary patterns, including the Healthy Eating Index 2015 (HEI-2015), Alternate Mediterranean Diet (AMED) score, Healthful Plant-based Diet Index (HPDI), and Alternate Healthy Eating Index (AHEI). We then examined their associations with total and cause-specific mortality. We also specifically examined these associations stratified by race and ethnicity and other potential risk factors.

## Methods

### Study Population

This cohort study used data from the Nurses' Health Study (NHS) and the Health Professionals Follow-up Study (HPFS). The NHS is a prospective cohort study of 121 700 female registered nurses aged 30 to 55 years from 11 US states that began in 1976. The HPFS is a prospective cohort study of 51 529 male health professionals aged 40 to 75 years at baseline that began in 1986. In both cohorts, information about medical history, lifestyle, and health conditions was collected by self-administered questionnaires at baseline and every 2 years thereafter. Detailed information on the cohorts is described elsewhere.<sup>18,19</sup> The study protocol was approved by the institutional review boards of the Brigham and Women's Hospital, Harvard T.H. Chan School of Public Health, and participating registries as required. The return of completed questionnaires was considered to imply informed consent. This study followed the Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

### Key Points

**Question** Is there an association between Dietary Guidelines for Americans–recommended dietary patterns with total and cause-specific mortality?

**Findings** In this cohort study of 75 230 women from the Nurses' Health Study (1984-2020) and 44 085 men from the Health Professionals Follow-Up Study (1986-2020), greater adherence to several healthy eating patterns was associated with a lower risk of death. These associations were consistent in different racial and ethnic groups, including Hispanic, non-Hispanic Black, and non-Hispanic White individuals.

**Meaning** These findings support the recommendations of Dietary Guidelines for Americans that multiple healthy eating patterns can be adapted to individual food traditions and preferences.

For the present analysis, baseline was defined as the year of the first validated food-frequency questionnaire providing enough information to derive the dietary indices in each study—1984 for the NHS and 1986 for the HPFS. We excluded participants who reported cardiovascular disease (CVD), cancer, or diabetes at baseline to reduce the probability of reverse causation because the diagnoses of these conditions might have led to changes in diet. We also excluded participants who did not provide information on diet and those who had daily energy intakes less than 600 kcal or greater than 3500 kcal for women and less than 800 kcal or greater than 4200 kcal for men.

### Assessment of Dietary Scores

Dietary information was collected with the use of a validated semiquantitative food frequency questionnaire (FFQ) with over 130 items administered every 2 to 4 years.<sup>20</sup> The reproducibility and validity of the FFQs have been described in detail elsewhere,<sup>21,22</sup> showing good correlation between nutrients assessed by the FFQs and multiple weeks of food records or biomarkers of diet. Using the food and nutrient components, we calculated the HEI-2015, AMED score, HPDI, and AHEI to measure adherence to the Healthy US-Style Eating Pattern, Alternate Mediterranean Eating Pattern, Healthy Plant-based Eating Pattern, and Alternate Healthy Eating Pattern. The components and scoring criteria for each dietary score are described in detail in eTables 1-4 and eMethods in Supplement 1. Briefly, the HEI-2015 includes 13 components and ranges from 0 to 100, with higher scores indicating higher adherence to DGAs. The AMED score includes 9 components and ranges from 9 to 45, with higher scores indicating a healthier Mediterranean diet. The HPDI includes 18 components and ranges from 18 to 90, with higher scores indicating a healthier plant-based diet. The AHEI, based on DGAs with modification to include factors related to chronic disease risk, includes 10 components and ranges from 0 to 100, with higher scores indicating a healthier diet. All dietary scores have shown moderate to high reproducibility and validity in both men and women.<sup>23</sup>

### Ascertainment of Deaths

Deaths were identified from state vital statistics records and the National Death Index or were reported by the participants' families and the US postal system. Using these meth-

Table 1. Baseline Characteristics of Participants According to Quintiles of the HEI-2015, AMED Score, HPDI, and AHEI

Characteristic	Participants <sup>a</sup>					AMED score					HPDI					AHEI				
	HEI-2015																			
	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5		
<b>Nurses' Health Study (1984)</b>																				
Participants, No	15 336	15 063	14 648	16 177	14 957	13 658	16 346	15 737	15 823	15 274	14 797									
Dietary score, mean (SD)	51.9 (5.0)	66.0 (1.4)	78.5 (3.9)	19.6 (2.2)	27.0 (0.8)	35.4 (2.2)	44.6 (3.2)	54.5 (1.1)	64.6 (3.3)	29.9 (3.5)	42.6 (1.5)	58.4 (5.7)								
Age, mean (SD), y	48.2 (7.0)	50.0 (7.1)	52.8 (6.8)	48.9 (7.1)	50.2 (7.1)	51.8 (7.0)	48.2 (7.0)	50.3 (7.1)	52.3 (6.8)	48.5 (7.1)	50.3 (7.1)	52.1 (6.8)								
<b>Race and ethnicity</b>																				
Hispanic	90 (0.6)	133 (0.9)	125 (0.9)	123 (0.8)	112 (0.7)	120 (0.9)	76 (0.5)	135 (0.8)	168 (1.1)	78 (0.5)	115 (0.8)	161 (1.1)								
Non-Hispanic Black	155 (1.0)	175 (1.2)	193 (1.3)	161 (1.0)	164 (1.1)	160 (1.1)	158 (1.0)	167 (1.1)	205 (1.3)	115 (0.8)	171 (1.1)	235 (1.6)								
Non-Hispanic White	14 419 (94.0)	14 285 (93.6)	13 679 (93.4)	15 171 (93.8)	14 072 (94.1)	12 752 (93.4)	15 487 (94.7)	14 708 (93.5)	14 701 (92.9)	14 515 (95.0)	14 116 (94.0)	13 620 (92.0)								
Other <sup>b</sup>	673 (4.4)	651 (4.3)	651 (4.4)	722 (4.4)	609 (4.1)	625 (4.6)	625 (3.8)	728 (4.6)	749 (4.7)	566 (3.7)	621 (4.1)	781 (5.3)								
Body mass index, mean (SD) <sup>c</sup>	25.2 (5.2)	25.1 (4.6)	24.3 (4.1)	25.1 (5.0)	25.0 (4.6)	24.6 (4.3)	25.4 (5.1)	24.9 (4.6)	24.3 (4.1)	25.1 (5.0)	25.1 (4.7)	24.5 (4.2)								
Physical activity, mean (SD), MET-h/w	9.43 (16.1)	12.9 (18.0)	17.3 (24.1)	9.54 (15.2)	12.7 (19.1)	17.8 (23.9)	10.5 (16.0)	12.7 (19.2)	16.6 (23.9)	9.37 (14.0)	12.8 (19.3)	18.0 (25.7)								
Never smoker	6 179 (40.3)	6 858 (45.5)	6 655 (45.4)	6 587 (40.7)	6 648 (44.4)	6 222 (45.6)	7 438 (45.5)	7 059 (44.9)	6 554 (41.4)	6 708 (43.9)	6 668 (44.4)	6 309 (42.6)								
Never drinker	5 592 (36.5)	4 390 (29.1)	4 261 (29.1)	6 915 (42.7)	4 422 (29.6)	2 760 (20.2)	5 111 (31.3)	4 778 (30.4)	4 839 (30.6)	5 302 (34.7)	4 450 (29.6)	4 383 (29.6)								
Premenopausal	6 308 (41.1)	6 335 (42.1)	5 961 (40.7)	6 666 (41.2)	6 208 (41.5)	5 642 (41.3)	6 987 (42.8)	6 502 (41.3)	6 357 (40.2)	6 437 (42.1)	6 261 (41.7)	6 043 (40.8)								
Married	9 950 (64.9)	10 495 (69.7)	10 265 (70.1)	10 481 (64.8)	10 402 (69.6)	9 721 (71.2)	11 060 (67.7)	10 845 (68.9)	11 023 (69.7)	10 498 (68.7)	10 314 (68.6)	10 130 (68.5)								
Live alone	1 502 (9.8)	1 424 (9.4)	1 534 (10.5)	1 695 (10.5)	1 434 (9.6)	1 334 (9.8)	1 585 (9.7)	1 503 (9.6)	1 657 (10.5)	1 307 (8.6)	1 435 (9.6)	1 678 (11.3)								
Total calorie intake, mean (SD), kcal/d	2 016 (568)	1 736 (497)	1 491 (427)	1 524 (489)	1 727 (506)	2 019 (526)	2 077 (505)	1 716 (497)	1 458 (439)	1 932 (492)	1 732 (536)	1 581 (504)								
Multivitamin supplement use	4 440 (29.0)	5 620 (37.3)	6 717 (45.9)	4 924 (30.4)	5 377 (36.0)	6 171 (45.2)	5 286 (32.3)	5 853 (37.2)	6 668 (42.1)	4 687 (30.7)	5 433 (36.2)	6 676 (45.1)								
Aspirin use	10 923 (71.2)	10 846 (72.0)	9 990 (68.2)	11 321 (70.0)	10 675 (71.4)	9 708 (71.1)	11 897 (72.8)	11 230 (71.4)	10 860 (68.6)	11 092 (72.6)	10 766 (71.2)	10 091 (68.2)								
<b>Family history</b>																				
Diabetes	4 397 (28.7)	4 426 (29.4)	4 001 (27.3)	4 707 (29.1)	4 253 (28.4)	3 850 (28.2)	4 666 (28.5)	4 490 (28.5)	4 510 (28.5)	4 407 (28.8)	4 398 (29.3)	4 197 (28.4)								
Myocardial infarction	3 891 (25.4)	3 718 (24.7)	3 717 (25.4)	4 110 (25.4)	3 764 (25.2)	3 564 (26.1)	3 966 (24.3)	3 897 (24.8)	4 147 (26.2)	3 816 (25.0)	3 802 (25.3)	3 835 (25.9)								
Cancer	2 075 (13.5)	2 254 (15.0)	2 094 (14.3)	2 169 (13.4)	2 128 (14.2)	2 017 (14.8)	2 340 (14.8)	2 312 (14.7)	2 271 (14.4)	2 180 (14.3)	2 126 (14.2)	2 152 (14.5)								
<b>Past diagnoses</b>																				
Hypertension	2 967 (19.4)	3 048 (20.2)	2 929 (20.0)	3 396 (21.0)	3 061 (20.5)	2 661 (19.5)	3 461 (21.2)	3 137 (19.9)	3 040 (19.2)	3 177 (20.8)	3 155 (21.0)	2 903 (19.6)								
High cholesterol level	2 28 (1.5)	2 57 (1.7)	3 81 (2.6)	2 64 (1.6)	2 90 (1.9)	3 38 (2.5)	2 47 (1.5)	2 97 (1.9)	3 94 (2.5)	2 30 (1.5)	3 06 (2.0)	3 49 (2.4)								
<b>Health Professionals Follow-up Study (1986)</b>																				
Participants, No	9 116	8 842	8 411	9 714	10 816	9 005	9 540	9 063	7 949	9 121	8 858	8 460								
Dietary score, mean (SD)	53.6 (5.3)	69.0 (1.6)	82.7 (3.7)	19.3 (2.4)	27.5 (1.1)	35.7 (2.5)	44.5 (3.2)	54.5 (1.1)	65.6 (3.3)	32.2 (4.2)	46.7 (1.6)	62.7 (5.2)								

(continued)

Table 1. Baseline Characteristics of Participants According to Quintiles of the HEI-2015, AMED Score, HPDI, and AHEI (continued)

Characteristic	Participants <sup>a</sup>					AMED score					HPDI					AHEI				
	HEI-2015					AMED score					HPDI					AHEI				
	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5		
Age, mean (SD), y	51.6 (9.3)	53.5 (9.7)	55.2 (9.6)	51.7 (9.4)	53.5 (9.6)	54.8 (9.6)	51.0 (9.3)	53.4 (9.6)	55.6 (9.4)	51.4 (9.3)	53.4 (9.6)	55.6 (9.4)	51.4 (9.3)	53.4 (9.7)	55.3 (9.5)	51.4 (9.3)	53.4 (9.7)	55.3 (9.5)		
White <sup>d</sup>	8265 (90.7)	8054 (91.1)	7692 (91.5)	8824 (90.8)	6875 (90.4)	8261 (91.7)	8795 (92.2)	8204 (90.5)	7200 (90.6)	8397 (92.1)	8019 (90.5)	7200 (90.6)	8397 (92.1)	8019 (90.5)	7714 (91.2)	8397 (92.1)	8019 (90.5)	7714 (91.2)		
Body mass index, mean (SD) <sup>c</sup>	25.8 (3.5)	25.7 (3.4)	24.8 (3.0)	25.8 (3.4)	25.5 (3.2)	25.0 (3.3)	25.6 (3.4)	25.6 (3.3)	25.1 (3.2)	25.8 (3.4)	25.6 (3.3)	25.1 (3.2)	25.8 (3.4)	25.6 (3.3)	25.0 (3.2)	25.8 (3.4)	25.6 (3.3)	25.0 (3.2)		
Physical activity, mean (SD), MET-h/w	15.9 (22.2)	20.6 (24.2)	27.2 (29.0)	15.1 (20.8)	20.4 (23.8)	28.1 (28.8)	17.9 (22.7)	20.0 (23.7)	25.8 (28.5)	15.5 (21.0)	20.3 (23.6)	25.8 (28.5)	15.5 (21.0)	20.3 (23.6)	27.3 (28.7)	15.5 (21.0)	20.3 (23.6)	27.3 (28.7)		
Never smoker	4054 (44.5)	4394 (49.7)	4639 (55.2)	4454 (45.9)	5404 (50.0)	4733 (52.6)	4865 (51.0)	4514 (49.8)	3793 (47.7)	4220 (46.3)	4500 (50.8)	3793 (47.7)	4220 (46.3)	4500 (50.8)	4401 (52.0)	4220 (46.3)	4500 (50.8)	4401 (52.0)		
Never drinker	2440 (26.7)	1892 (21.4)	1918 (22.8)	3131 (32.2)	2355 (21.8)	1336 (14.8)	2197 (23.0)	2039 (22.5)	1903 (23.9)	2266 (24.8)	1987 (22.4)	1903 (23.9)	2266 (24.8)	1987 (22.4)	1875 (22.2)	2266 (24.8)	1987 (22.4)	1875 (22.2)		
Married	8060 (88.4)	8077 (91.3)	7585 (90.2)	8601 (88.5)	9795 (90.6)	8195 (91.0)	8544 (89.6)	8197 (90.5)	7201 (90.6)	8197 (89.9)	8005 (90.4)	7201 (90.6)	8197 (89.9)	8005 (90.4)	7658 (90.5)	8197 (89.9)	8005 (90.4)	7658 (90.5)		
Live alone	643 (7.1)	472 (5.3)	530 (6.3)	696 (7.2)	625 (5.8)	497 (5.5)	621 (6.5)	533 (5.9)	480 (6.0)	577 (6.3)	531 (6.0)	480 (6.0)	577 (6.3)	531 (6.0)	476 (5.6)	577 (6.3)	531 (6.0)	476 (5.6)		
Total calorie intake, mean (SD), kcal/d	2283 (678)	1975 (580)	1724 (498)	1768 (569)	1980 (602)	2265 (618)	2351 (616)	1944 (580)	1703 (517)	2120 (595)	1979 (636)	1703 (517)	2120 (595)	1979 (636)	1893 (589)	2120 (595)	1979 (636)	1893 (589)		
Multivitamin supplement use	3151 (34.6)	3577 (40.5)	4357 (51.8)	3434 (35.4)	4501 (41.6)	4526 (50.3)	3432 (36.0)	3770 (41.6)	3848 (48.4)	3230 (35.4)	3673 (41.5)	3848 (48.4)	3230 (35.4)	3673 (41.5)	4215 (49.8)	3230 (35.4)	3673 (41.5)	4215 (49.8)		
Aspirin use	2515 (27.6)	2436 (27.6)	2295 (27.3)	2501 (25.7)	3096 (28.6)	2641 (29.3)	2637 (27.6)	2489 (27.5)	2295 (28.9)	2537 (27.8)	2410 (27.2)	2295 (28.9)	2537 (27.8)	2410 (27.2)	2304 (27.2)	2537 (27.8)	2410 (27.2)	2304 (27.2)		
Family history																				
Diabetes	1808 (19.8)	1787 (20.2)	1700 (20.2)	1996 (20.6)	2153 (19.9)	1863 (20.7)	1933 (20.3)	1885 (20.8)	1674 (21.1)	1766 (19.4)	1828 (20.6)	1674 (21.1)	1766 (19.4)	1828 (20.6)	1778 (21.0)	1766 (19.4)	1828 (20.6)	1778 (21.0)		
Myocardial infarction	2740 (30.1)	2937 (33.2)	2954 (35.1)	2932 (30.2)	3534 (32.7)	3122 (34.7)	2925 (30.7)	2935 (32.4)	2821 (35.5)	2764 (30.3)	2887 (32.6)	2821 (35.5)	2764 (30.3)	2887 (32.6)	2999(35.5)	2764 (30.3)	2887 (32.6)	2999(35.5)		
Cancer	3076 (33.8)	3052 (34.5)	2910 (34.6)	3209 (33.0)	3748 (34.7)	3141 (34.9)	3357 (35.2)	3069 (33.9)	2671 (33.6)	3084 (33.8)	3040 (34.3)	2671 (33.6)	3084 (33.8)	3040 (34.3)	2925 (34.6)	3084 (33.8)	3040 (34.3)	2925 (34.6)		
Past diagnoses																				
Hypertension	1856 (20.4)	2058 (23.3)	2078 (24.7)	2177 (22.4)	2482 (23.0)	2084 (23.1)	1969 (20.6)	2093 (23.1)	1967 (24.8)	1895 (20.8)	2084 (23.5)	1967 (24.8)	1895 (20.8)	2084 (23.5)	2047 (24.2)	1895 (20.8)	2084 (23.5)	2047 (24.2)		
High cholesterol level	754 (8.3)	907 (10.3)	1348 (16.0)	823 (8.5)	1124 (10.4)	1383 (15.4)	757 (7.9)	931 (10.3)	1234 (15.5)	750 (8.2)	961 (10.9)	1234 (15.5)	750 (8.2)	961 (10.9)	1234 (14.6)	750 (8.2)	961 (10.9)	1234 (14.6)		

Abbreviations: AHEI, Alternate Healthy Eating Index; AMED, Alternate Mediterranean Diet; HEI-2015, Healthy Eating Index 2015; HPDI, Healthful Plant-based Diet Index; MET, metabolic equivalent.

<sup>a</sup> Data are presented as number (percentage) of participants unless otherwise indicated. All variables except age are age-standardized.

<sup>b</sup> Includes American Indian, Asian, Hawaiian, and multiracial.

<sup>c</sup> Calculated as weight in kilograms divided by height in meters squared.

<sup>d</sup> No other detailed racial and ethnic group information was available in the Health Professionals Follow-up Study.

ods, 98% of the deaths in each cohort were ascertained.<sup>24</sup> We attempted to obtain the death certificate of each participant who had died and, when appropriate, requested permission from the participant's next of kin to review medical records. The classification of the cause of death was mostly based on review of medical records. A physician reviewed medical records and death certificates to classify the cause of death according to the *International Classification of Diseases, Revision 8*, and *International Classification of Diseases, Ninth Revision (ICD-9)*. Deaths were grouped into deaths from CVD (ICD-9: 390-459), cancer (ICD-9: 140-208), neurodegenerative disease (ICD-9: 290, 332, 335, 340, 342, and 348), respiratory disease (ICD-9: 460-519), and all other causes.

### Ascertainment of Covariates

Participants reported their race and ethnicity in NHS according to categories (Hispanic, non-Hispanic Black, non-Hispanic White, and other [American Indian, Asian, Hawaiian, and multiracial]) provided by the investigators. The HPFS does not have information on ethnicity; thus, stratified analysis by race and ethnicity was not conducted in this cohort. Every 2 years, participants returned a mailed validated questionnaire that obtained updated information on their lifestyle and other risk factors, including age, body weight, smoking status, physical activity, aspirin use, multivitamin use, menopausal status and postmenopausal hormone use in women, and physician diagnosis of chronic diseases.<sup>25</sup> Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.

### Statistical Analysis

To best represent long-term intake and dampen within-person variation in the NHS and HPFS cohorts, we calculated cumulative mean dietary scores up to the start of each 2-year follow-up interval. Person-years were calculated from the date of return of the baseline questionnaire to the date of death or the end of follow-up (June 2020 for both NHS and HPFS), whichever occurred first. We did not censor participants lost to active follow-up because fatal events were included in the outcomes. We stopped updating dietary variables after report of incident diabetes, CVD, or cancer because changes in diet after the development of these conditions may confound the estimates. We used Cox proportional hazards regression models with age as the underlying time scale, with stratification by calendar time, to assess the association between 4 dietary scores and the subsequent risk of total and cause-specific mortality. The proportional-hazards assumption was evaluated with a likelihood-ratio test comparing the model with and without an interaction term between age and dietary scores. In multivariable analysis, we adjusted for age, race and ethnicity, family history of CVD, family history of cancer, and time-dependent confounders, including marital status, living alone or with others, postmenopausal status and hormone use (NHS), smoking status, physical activity, alcohol intake (not for AMED), multivitamin use, aspirin use, total energy intake, and BMI. Tests for linear trends across quintiles were conducted by assigning a median value to each quintile of dietary score, producing a single ordinal variable used in the

model. We also used the restricted cubic spline analysis to flexibly model the association between 4 dietary scores and total mortality. Additionally, a 25-percentile difference in each score (25 points for HEI-2015, 9 points for AMED score, 18 points for HPDI, and 25 points for AHEI) was calculated from the range of total dietary scores. Separate analyses were conducted for cause-specific mortality per a 25-percentile difference in each score. All analyses were performed separately for each cohort and then were pooled with the use of fixed-effects meta-analysis with inverse-variance weighting, and the heterogeneity was assessed with the  $I^2$  statistic.

We conducted stratified analyses defined a priori by race and ethnicity (NHS) and other potential risk modifiers. The interactions between each of the 4 dietary scores and covariates were examined using the likelihood ratio test. The interactions should be interpreted as exploratory because these findings might be due to chance from multiple testing. We performed several sensitivity analyses to test the robustness of our results. First, we conducted lagged analyses by excluding the first 4 years of follow-up data and adding a 4-year lag period between assessment of dietary intake and each follow-up period to address concern that chronic disease occurrence may influence dietary behavior. Second, to test whether our results were biased by selectively stopping updating diet after an intermediate outcome, we continuously updated diet until the end of follow-up. Third, we analyzed the associations of baseline dietary scores with total mortality. Fourth, given the potential heterogeneity between 2 cohorts, the results were pooled using random effects. Fifth, we applied a competing risk regression model for cause-specific mortality by including dietary scores as exposure and other risk factors as unconstrained covariates, allowing the effects of the covariates to vary across cause-specific mortality.<sup>26</sup> All analyses were performed with the SAS, version 9.4 (SAS Institute). All statistical tests were 2 sided, and  $P < .05$  was considered to indicate statistical significance.

## Results

The final study sample included 75 230 women from the NHS (mean [SD] baseline age, 50.2 [7.2] years) and 44 085 men from the HPFS (mean [SD] baseline age, 53.3 [9.6] years). **Table 1** shows age and the age-adjusted characteristics of study participants at baseline according to quintiles of the 4 dietary scores. In both cohorts, participants with higher dietary scores tended to be older, less likely to smoke, and more likely to exercise and to have a lower BMI (Table 1). In the NHS at baseline, 597 (1.1%) were Hispanic, 834 participants (0.8%) were non-Hispanic Black, 70 564 (98.0%) were non-Hispanic White, and 3235 (4.3%) were other race and ethnicity. In the HPFS at baseline, 412 participants (0.9%) were Black, 40 099 (91.0%) were White, and 3574 (8.1%) were other race and ethnicity. The correlations between 4 dietary scores ranged from moderately low to moderately high ( $r = 0.39$ - $0.75$ ).

In the NHS, during up to 36 years of follow-up (2 343 144 person-years), we documented 31 263 deaths, including 6128 deaths from CVD and 8733 deaths from cancer; in the HPFS

**Table 2. Hazard Ratios of Death From Any Cause According to Quintiles of the HEI-2015, AMED score, HPDI, and AHEI**

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P value for trend
<b>HEI-2015</b>						
<b>NHS</b>						
Score, median (IQR)	56 (52-59)	64 (62-65)	69 (67-70)	73 (72-74)	79 (77-82)	NA
Cases/PYs	6291/439 732	6100/462 519	6195/475 859	6197/484 161	6480/480 873	NA
Age-adjusted HR (95% CI)	1 [Reference]	0.80 (0.77-0.83)	0.72 (0.70-0.75)	0.65 (0.63-0.67)	0.57 (0.55-0.59)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.89 (0.86-0.93)	0.87 (0.84-0.90)	0.82 (0.79-0.85)	0.76 (0.73-0.79)	<.001
<b>HPFS</b>						
Score, median (IQR)	57 (53-60)	65 (63-66)	70 (69-72)	75 (74-77)	82 (80-85)	NA
Cases/PYs	4560/237 489	4532/245 889	4566/246 767	4553/249 794	4689/235 973	NA
Age-adjusted HR (95% CI)	1 [Reference]	0.85 (0.82-0.89)	0.78 (0.75-0.82)	0.72 (0.69-0.75)	0.68 (0.66-0.71)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.97 (0.93-1.01)	0.94 (0.90-0.98)	0.89 (0.85-0.93)	0.90 (0.86-0.94)	<.001
<b>Pooled</b>						
Age-adjusted HR (95% CI)	1 [Reference]	0.82 (0.80-0.84)	0.75 (0.73-0.77)	0.68 (0.66-0.70)	0.62 (0.60-0.63)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.92 (0.90-0.95)	0.90 (0.87-0.92)	0.85 (0.83-0.87)	0.81 (0.79-0.84)	<.001
<b>AMED score</b>						
<b>NHS</b>						
Score, median (IQR)	20 (19-22)	24 (23-25)	27 (26-28)	30 (29-31)	34 (32-35)	NA
Cases/PYs	6373/443 032	6660/477 671	6373/468 492	6078/492 732	5779/461 217	NA
Age-adjusted HR (95% CI)	1 [Reference]	0.83 (0.80-0.86)	0.76 (0.73-0.78)	0.69 (0.66-0.71)	0.65 (0.63-0.67)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.90 (0.87-0.94)	0.86 (0.83-0.89)	0.80 (0.77-0.83)	0.77 (0.74-0.81)	<.001
<b>HPFS</b>						
Score, median (IQR)	20 (18-22)	24 (23-25)	27 (27-28)	31 (30-31)	35 (33-37)	NA
Cases/PYs	4434/243 269	4629/237 941	4725/258 396	4595/239 235	4517/237 070	NA
Age-adjusted HR (95% CI)	1 [Reference]	0.89 (0.85-0.92)	0.81 (0.78-0.84)	0.76 (0.73-0.79)	0.72 (0.69-0.75)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.97 (0.93-1.01)	0.92 (0.88-0.96)	0.88 (0.85-0.91)	0.87 (0.84-0.90)	<.001
<b>Pooled</b>						
Age-adjusted HR (95% CI)	1 [Reference]	0.85 (0.83-0.87)	0.78 (0.76-0.80)	0.72 (0.70-0.74)	0.68 (0.66-0.70)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.93 (0.90-0.95)	0.89 (0.86-0.91)	0.83 (0.81-0.86)	0.82 (0.79-0.84)	<.001
<b>HPDI</b>						
<b>NHS</b>						
Score, median (IQR)	46 (44-48)	51 (50-52)	55 (54-56)	58 (57-59)	63 (62-66)	NA
Cases/PYs	5889/459 000	6298/480 456	6384/484 214	6535/468 647	6157/450 827	NA
Age-adjusted HR (95% CI)	1 [Reference]	0.89 (0.86-0.92)	0.82 (0.79-0.85)	0.80 (0.77-0.83)	0.72 (0.70-0.75)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.93 (0.90-0.97)	0.88 (0.85-0.92)	0.87 (0.84-0.90)	0.80 (0.77-0.83)	<.001
<b>HPFS</b>						
Score, median (IQR)	46 (44-48)	51 (50-52)	55 (54-56)	59 (58-60)	64 (62-67)	NA
Cases/PYs	4316/251 063	4658/253 138	4716/245 702	4757/247 849	4453/218 159	NA
Age-adjusted HR (95% CI)	1 [Reference]	0.95 (0.91-0.99)	0.89 (0.85-0.93)	0.85 (0.82-0.89)	0.84 (0.80-0.87)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	1.00 (0.96-1.04)	0.97 (0.93-1.01)	0.96 (0.92,1.00)	0.95 (0.91-0.99)	.006
<b>Pooled</b>						
Age-adjusted HR (95% CI)	1 [Reference]	0.91 (0.89-0.94)	0.85 (0.83-0.87)	0.82 (0.80-0.84)	0.77 (0.75-0.79)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.96 (0.93-0.99)	0.92 (0.89-0.95)	0.91 (0.88-0.93)	0.86 (0.83-0.89)	<.001
<b>AHEI</b>						
<b>NHS</b>						
Score, median (IQR)	34 (31-36)	41 (39-42)	46 (44-47)	51 (49-52)	59 (56-62)	NA
Cases/PYs	6285/443 704	6533/477 209	6512/482 114	6240/481 477	5693/458 639	NA
Age-adjusted HR (95% CI)	1 [Reference]	0.83 (0.80-0.86)	0.75 (0.73-0.78)	0.68 (0.66-0.71)	0.61 (0.59-0.63)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.90 (0.87-0.94)	0.86 (0.83-0.89)	0.81 (0.79-0.84)	0.75 (0.72-0.77)	<.001

(continued)

Table 2. Hazard Ratios of Death From Any Cause According to Quintiles of the HEI-2015, AMED score, HPDI, and AHEI (continued)

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P value for trend
HPFS						
Score, median (IQR)	35 (32-37)	42 (41-44)	48 (46-49)	53 (52-55)	61 (59-65)	NA
Cases/PYs	4443/239 791	4710/246 148	4617/250 070	4576/245 755	4554/234 148	NA
Age-adjusted HR (95% CI)	1 [Reference]	0.88 (0.85-0.92)	0.79 (0.76-0.83)	0.73 (0.70-0.76)	0.69 (0.67-0.72)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.98 (0.94-1.02)	0.91 (0.87-0.95)	0.88 (0.84-0.92)	0.87 (0.83-0.91)	<.001
Pooled						
Age-adjusted HR (95% CI)	1 [Reference]	0.85 (0.83-0.87)	0.77 (0.75-0.79) <sup>b</sup>	0.70 (0.68-0.72)	0.64 (0.63-0.66)	<.001
Multivariable adjusted HR (95% CI) <sup>a</sup>	1 [Reference]	0.93 (0.91-0.96)	0.88 (0.86-0.91)	0.84 (0.82-0.86)	0.80 (0.77-0.82)	<.001

Abbreviations: AHEI, Alternate Healthy Eating Index; AMED, Alternate Mediterranean Diet; HEI-2015, Healthy Eating Index 2015; HPDI, Healthful Plant-based Diet Index; HPFS, Health Professionals Follow-Up Study; HR, hazard ratio; NA, not applicable; NHS, Nurses' Health Study; PY, person-years.

<sup>a</sup> Multivariable analysis was adjusted for age, calendar year, race and ethnicity (NHS: Hispanic, non-Hispanic Black, non-Hispanic White, or other; HPFS, Black, White, or other), marriage status (married; divorced, separated, or single; or widowed), living status (alone or not alone), family history of myocardial infarction (yes or no), family history of diabetes (yes or no), family history of cancer (yes or no), menopausal status (pre- or postmenopausal

[never, past, or current menopausal hormone use]; NHS only), multivitamin use (yes or no), aspirin use (yes or no), total energy intake (quintile), smoking status (never, former, or current smoker [1-14, 15-24, or  $\geq 25$  cigarettes/d), alcohol drinking (0, 0.1-4.9, 5.0-14.9, 15.0-19.9, 20.0-29.9, or  $\geq 30$  g/d), physical activity (quintile), history of hypertension (yes or no), history of hypercholesterolemia (yes or no), and body mass index (<21, 21-24.9, 25-29.9, 30-34.9, or  $\geq 35$  [calculated as weight in kilograms divided by height in meters squared]).

<sup>b</sup> Represents  $I^2$  less than 75%.

during 34 years of follow-up (1 215 912 person-years), we documented 22 900 deaths, including 6641 deaths from CVD and 5710 deaths from cancer. After adjustment for potential confounders, when comparing the highest with the lowest quintiles, the pooled HRs of all-cause mortality were 0.81 (95% CI, 0.79-0.84) for HEI-2015, 0.82 (95% CI, 0.79-0.84) for AMED score, 0.86 (95% CI, 0.83-0.89) for HPDI, and 0.80 (95% CI, 0.77-0.82) for AHEI ( $P < .001$  for trend for all) (Table 2 and eFigure 1 in Supplement 1).

In multivariate analyses, the 4 dietary scores were inversely associated with the risk of most major causes of death. In the pooled analysis of women and men, significant inverse associations were observed between 4 dietary scores and deaths due to CVD (HEI-2015: HR, 0.87 [95% CI, 0.83-0.92]; AMED score: HR, 0.94 [95% CI, 0.91-0.97]; HPDI: HR, 0.94 [95% CI, 0.89-0.99]; and AHEI: HR, 0.88 [95% CI, 0.84-0.92]), cancer (HEI-2015: HR, 0.82 [95% CI, 0.78-0.86]; AMED score: HR, 0.93 [95% CI, 0.90-0.96]; HPDI: HR, 0.90 [95% CI, 0.86-0.95]; and AHEI: HR, 0.84 [95% CI, 0.81-0.88]), and respiratory disease (HEI-2015: HR, 0.54 [95% CI, 0.49-0.59]; AMED score: HR, 0.65 [95% CI, 0.61-0.69]; HPDI: HR, 0.63 [95% CI, 0.58-0.70]; and AHEI: HR, 0.56 [95% CI, 0.52-0.61]) (Table 3 and eTables 5-8 in Supplement 1). The AMED score and AHEI were associated with lower risk of mortality caused by neurodegenerative disease. For deaths from the top 3 cancers among men and women, consistent inverse associations were observed between the 4 dietary scores and death from lung cancer in both men and women (eTable 9 in Supplement 1).

The baseline characteristics, including the dietary scores, were similar across different racial and ethnic groups in the NHS (eTable 10 in Supplement 1). The associations between dietary patterns and total mortality did not differ significantly by race and ethnicity; the HRs of total mortality per 25-percentile difference in HEI-2015 were 0.55 (95% CI, 0.33-0.89;  $P = .21$  for interaction) in Hispanic women, 0.59 (95% CI, 0.41-0.84;  $P = .19$  for interaction) in non-Hispanic Black

women, 0.75 (95% CI, 0.72-0.78) in non-Hispanic White women, and 0.72 (95% CI, 0.62-0.85;  $P = .65$  for interaction) in other racial and ethnic minority groups (Figure). Similar results were found for AMED score, HPDI, and AHEI. In subgroup analyses by other potential risk factors for death, the inverse association between dietary scores and total mortality persisted in all subgroups (Table 4). Significant interactions were detected between 4 dietary scores and total mortality by sex and smoking status; HRs were higher among women than among men and among current and ever smokers than among never smokers. The significant inverse associations between dietary scores and total mortality remained largely unchanged when pack-years of smoking were further adjusted (eTable 11 in Supplement 1), the baseline and simple updated dietary data were used (eTables 12 and 13 in Supplement 1), the diet was continuously updated until the end of follow-up (eTable 14 in Supplement 1), and the random-effects model was used (eTables 15 and 16 in Supplement 1). When applying a competing risk regression model for cause-specific mortality, the results remained consistent with those from the primary analysis (eTable 17 in Supplement 1).

## Discussion

In this cohort study of 2 large prospective cohorts, we found a significant dose-dependent inverse association between adherence to various dietary patterns and total mortality after adjusting for potential confounders. The inverse associations were observed for mortality from CVD, cancer, and respiratory diseases and persisted across different racial and ethnic groups and other subgroups.

Our results are generally consistent with previous studies that reported inverse associations between individual dietary scores and all-cause mortality. The Atherosclerosis Risk in Communities (ARIC) study,<sup>14</sup> the Dietary Patterns Meth-

Table 3. Hazard Ratios for Death From Specific Causes According to 4 Healthy Eating Scores<sup>a</sup>

Cause of death	Cases, No.	Hazard ratio (95% CI)			
		HEI-2015	AMED score	HPDI	AHEI
<b>NHS</b>					
Cardiovascular disease	6128	0.77 (0.72-0.83)	0.86 (0.82-0.91)	0.85 (0.78-0.92)	0.77 (0.71-0.83)
Heart disease	4330	0.74 (0.68-0.81)	0.85 (0.80-0.90)	0.81 (0.74-0.89)	0.74 (0.68-0.81)
Stroke	1798	0.85 (0.74-0.98)	0.90 (0.82-0.99)	0.94 (0.81-1.09)	0.85 (0.74-0.97)
Cancer	8733	0.82 (0.76-0.87)	0.95 (0.91-0.99)	0.91 (0.85-0.98)	0.83 (0.78-0.88)
Respiratory disease	2491	0.44 (0.39-0.49)	0.57 (0.52-0.61)	0.50 (0.44-0.57)	0.45 (0.40-0.51)
Neurodegenerative disease	5004	1.04 (0.96-1.13)	0.96 (0.90-1.01)	0.96 (0.88-1.05)	0.94 (0.87-1.01)
<b>HPFS</b>					
Cardiovascular disease	6641	0.97 (0.90-1.04)	1.00 (0.96-1.05)	1.02 (0.95-1.10)	0.97 (0.91-1.04)
Heart disease	5386	0.94 (0.87-1.02)	1.00 (0.95-1.05)	0.99 (0.92-1.08)	0.94 (0.87-1.01)
Stroke	1255	1.11 (0.94-1.31)	1.02 (0.92-1.13)	1.13 (0.96-1.33)	1.12 (0.97-1.29)
Cancer	5710	0.82 (0.76-0.89)	0.91 (0.87-0.96)	0.89 (0.82-0.96)	0.86 (0.81-0.92)
Respiratory disease	1738	0.71 (0.62-0.81)	0.76 (0.70-0.83)	0.84 (0.73-0.96)	0.72 (0.63-0.81)
Neurodegenerative disease	2101	0.98 (0.86-1.11)	0.92 (0.85-0.99)	0.94 (0.83-1.06)	0.92 (0.82-1.03)
<b>Pooled</b>					
Cardiovascular disease	12 769	0.87 (0.83-0.92)	0.94 (0.91-0.97)	0.94 (0.89-0.99)	0.88 (0.84-0.92)
Heart disease	9716	0.85 (0.80-0.90)	0.94 (0.90-0.97)	0.92 (0.86-0.97)	0.85 (0.81-0.90)
Stroke	3053	0.96 (0.86-1.06)	0.95 (0.89-1.02) <sup>b</sup>	1.02 (0.92-1.14) <sup>b</sup>	0.96 (0.87-1.06)
Cancer	14 443	0.82 (0.78-0.86) <sup>b</sup>	0.93 (0.90-0.96) <sup>b</sup>	0.90 (0.86-0.95) <sup>b</sup>	0.84 (0.81-0.88) <sup>b</sup>
Respiratory disease	4229	0.54 (0.49-0.59)	0.65 (0.61-0.69)	0.63 (0.58-0.70)	0.56 (0.52-0.61)
Neurodegenerative disease	7105	1.02 (0.95-1.09) <sup>b</sup>	0.94 (0.90-0.99) <sup>b</sup>	0.95 (0.89-1.02) <sup>b</sup>	0.93 (0.87-0.99) <sup>b</sup>

Abbreviations: AHEI, Alternate Healthy Eating Index; AMED, Alternate Mediterranean Diet; HEI-2015, Healthy Eating Index 2015; HPDI, Healthful Plant-based Diet Index; HPFS, Health Professionals Follow-Up Study; NHS, Nurses' Health Study.

<sup>a</sup> Calculated per 25-percentile increment in 4 healthy eating scores (25 points for HEI-2015, 9 points for AMED score, 18 points for HPDI, and 25 points for AHEI-2010). Multivariable analysis was adjusted for age, calendar year, race and ethnicity (NHS: Hispanic, non-Hispanic Black, non-Hispanic White, or other; HPFS, Black, White, or other), marriage status (married; divorced, separated, or single; or widowed), living status (alone or not alone), family history of myocardial infarction (yes or no), family history of diabetes (yes or

no), family history of cancer (yes or no), menopausal status (pre- or postmenopausal [never, past, or current menopausal hormone use]; NHS only), multivitamin use (yes or no), aspirin use (yes or no), total energy intake (quintile), smoking status (never, former, or current smoker [1-14, 15-24, or  $\geq 25$  cigarettes/d), alcohol drinking (0, 0.1-4.9, 5.0-14.9, 15.0-19.9, 20.0-29.9, or  $\geq 30$  g/d), physical activity (quintile), history of hypertension (yes or no), history of hypercholesterolemia (yes or no), and body mass index ( $< 21$ , 21-24.9, 25-29.9, 30-34.9, or  $\geq 35$  [calculated as weight in kilograms divided by height in meters squared]).

<sup>b</sup> Represents  $I^2$  less than 75%.

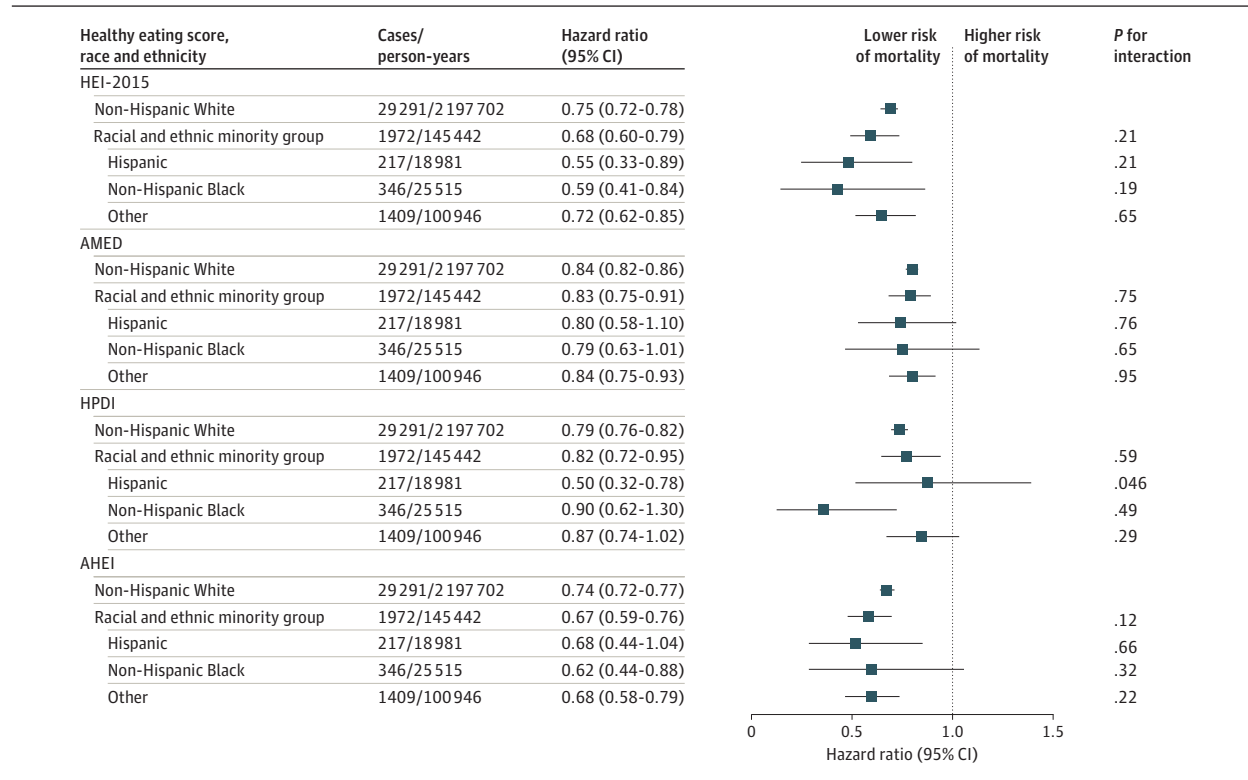
ods Project,<sup>13</sup> and the Women's Health Initiative Observational Study<sup>27</sup> found similar inverse associations in direction and magnitude for HEI-2015, AHEI, and AMED. When comparing the associations between 4 dietary scores of healthy eating patterns, the HRs of mortality associated with HEI-2015 and AHEI were higher than those for AMED and HPDI. These results are partly in line with previous findings that relative risk of death over 12 years was lower when diet quality was assessed by the AHEI than the AMED score.<sup>28</sup> However, in the ARIC study, the relative risks were lower for the AMED than for HEI-2015 and AHEI.<sup>14</sup> The reason for the similarity in the associations between the diet quality scores and mortality is probably that these dietary patterns share several components, such as whole grains, fruits, vegetables, nuts, and legumes. However, there are also some distinct components for each dietary score; for example, the AMED score encourages fish intake, but the HPDI discourages all animal foods. Accordingly, the correlations between 4 dietary scores ranged from moderately low to moderately high ( $r = 0.39$ - $0.75$ ). Our findings support the recommendations of the current DGAs to achieve long-term health benefits by adherence to various healthy eating patterns that can be adopted based on indi-

viduals' health needs, food preferences, and cultural traditions, although all these diet patterns encourage high consumption of healthy plant-based foods.

Our study provided additional data supporting inverse associations of healthy eating patterns with cause-specific mortality. The deaths in our study were mainly attributable to major chronic diseases, including CVD, cancer, respiratory disease, and neurodegenerative disease. Consistent with previous studies on CVD incidence and mortality,<sup>16,29</sup> we found an inverse association between each healthy eating score and CVD mortality. Our results of lower HRs for the AHEI and HEI-2015 than for the AMED score were expected given that the AHEI and HEI-2015 are mostly based on current knowledge of dietary factors contributing to cardiovascular disease.<sup>30,31</sup> The current evidence on healthy eating patterns and cancer mortality remains controversial.<sup>32,33</sup> Our data support that healthy eating patterns may be associated with reduced mortality from all cancers, but the presence of associations varied for mortality due to specific cancer, which were consistent with some previous findings for incidence of these specific cancers.<sup>34-38</sup> Previous data on healthy eating patterns and mortality attributable to respiratory disease are sparse. The Singapore Chinese Health



Figure. Hazard Ratios of Death From Any Cause According to 4 Healthy Eating Scores Across Racial and Ethnic Groups in the Nurses' Health Study



Multivariable analysis was adjusted for age, calendar year, marriage status (married; divorced, separated, or single; or widowed), living status (alone or not alone), family history of myocardial infarction (yes or no), family history of diabetes (yes or no), family history of cancer (yes or no), menopausal status (pre- or postmenopausal [never, past, or current menopausal hormone use]; Nurses' Health Study only), multivitamin use (yes or no), aspirin use (yes or no), total energy intake (quintile), smoking status (never, former, or current smoker

[1-14, 15-24, or  $\geq 25$  cigarettes/d]), alcohol drinking (0, 0.1-4.9, 5.0-14.9, 15.0-19.9, 20.0-29.9, or  $\geq 30$  g/d), physical activity (quintile), history of hypertension (yes or no), history of hypercholesterolemia (yes or no), and body mass index ( $< 21$ , 21-24.9, 25-29.9, 30-34.9, or  $\geq 35$  [calculated as weight in kilograms divided by height in meters squared]). AHEI indicates Alternate Healthy Eating Index; AMED, Alternate Mediterranean Diet; HEI-2015, Healthy Eating Index 2015; HPDI, Healthful Plant-based Diet Index.

Study<sup>39</sup> found similar results between various dietary patterns and respiratory disease mortality. In addition, a previous study by some of us found that a healthy dietary pattern was associated with a lower risk of chronic obstructive pulmonary disease.<sup>40</sup> In the present study, we found an association of the AMED score and AHEI with reduced neurodegenerative disease mortality, which may suggest benefits of some unique dietary components in 2 dietary patterns, such as nuts and monounsaturated fat.<sup>41,42</sup> However, these findings require confirmation in further studies.

Our study observed consistent inverse associations between individual dietary scores and total mortality across different subgroups, supporting the protective association of various healthy eating patterns with mortality among individuals with diverse cultural food traditions. Consistent inverse associations between individual dietary scores and risk of total mortality across racial and ethnic groups were found among women, and no significant interaction was detected, which was generally in line with previous findings on the HEI, AHEI, and AMED score in relation to mortality from the Multiethnic Cohort<sup>13</sup> and the ARIC study.<sup>14</sup> Considering the same profession of all participants and the relatively limited sample size of racial and ethnic minority individuals in the present study, further studies are warranted to confirm these findings.

### Strengths and Limitations

Strengths of the present study include a direct comparison of multiple dietary patterns, long-term and repeated measures of diet, multiple racial and ethnic groups, and observed associations between dietary quality scores and respiratory and neurological disease mortality. However, the study has certain limitations. First, because dietary intake information was self-reported, some measurement error was inevitable. However, the FFQs used in the present study were extensively validated against diet records and biomarkers. Second, the possibility of residual and unmeasured confounding could not be completely ruled out because of the observational nature of the study. Third, we did not examine the association between each dietary component and mortality because we considered diet as a combination of multiple components that act synergistically. Fourth, generalizability may be limited because participants were mostly health professionals.

### Conclusions

In this cohort study, greater adherence to various healthy eating patterns was consistently associated with a lower risk

**Table 4. Pooled Hazard Ratios of Death From Any Cause According to 4 Healthy Eating Scores Across Subgroups<sup>a</sup>**

Subgroup	HEI-2015	P value for interaction	AMED score	P value for interaction	HPDI	P value for interaction	AHEI	P value for interaction
<b>Age, y</b>								
<65	0.80 (0.75-0.87)	.87	0.84 (0.80-0.88)	.055	0.82 (0.76-0.89)	.15	0.77 (0.72-0.83)	.19
≥65	0.81 (0.79-0.83)		0.88 (0.87-0.90)		0.87 (0.85-0.90)		0.81 (0.79-0.83)	
<b>Sex</b>								
Female	0.76 (0.73-0.78)	<.001	0.85 (0.83-0.87)	<.001	0.80 (0.77-0.83)	<.001	0.75 (0.73-0.77)	<.001
Male	0.88 (0.84-0.91)		0.91 (0.89-0.94)		0.94 (0.90-0.98)		0.88 (0.85-0.91)	
<b>Race<sup>b</sup></b>								
Racial minority groups <sup>c</sup>	0.80 (0.72-0.90)	.93	0.90 (0.84-0.97)	.48	0.90 (0.81-1.01)	.41	0.81 (0.73-0.90)	.98
White	0.81 (0.79-0.83)		0.88 (0.86-0.89)		0.86 (0.84-0.88)		0.81 (0.79-0.83)	
<b>Smoking status</b>								
Never	0.92 (0.88-0.96)	<.001	0.95 (0.92-0.98)	<.001	0.95 (0.91-1.00)	<.001	0.90 (0.86-0.93)	<.001
Past	0.76 (0.73-0.78)		0.85 (0.83-0.86)		0.81 (0.78-0.84)		0.76 (0.74-0.78)	
Current	0.78 (0.72-0.84)		0.85 (0.81-0.90)		0.86 (0.79-0.94)		0.77 (0.71-0.84)	
<b>Alcohol consumption</b>								
Ever	0.80 (0.77-0.83)	.48	0.88 (0.86-0.90)	<.001	0.87 (0.84-0.90)	.36	0.81 (0.78-0.84)	.91
Never	0.82 (0.79-0.85)		0.93 (0.91-0.96)		0.85 (0.82-0.89)		0.81 (0.78-0.84)	
<b>Physical activity</b>								
Inactive	0.86 (0.83-0.88)	.11	0.91 (0.89-0.93)	.15	0.90 (0.87-0.93)	.61	0.85 (0.82-0.88)	.17
Active	0.82 (0.79-0.86)		0.89 (0.86-0.91)		0.89 (0.85-0.92)		0.82 (0.79-0.85)	
<b>BMI</b>								
<25	0.78 (0.75-0.81)	.01	0.86 (0.84-0.88)	.002	0.83 (0.79-0.86)	.001	0.78 (0.75-0.80)	.003
25-29.9	0.84 (0.81-0.88)		0.89 (0.86-0.91)		0.92 (0.88-0.96)		0.85 (0.82-0.88)	
≥30	0.83 (0.77-0.89)		0.94 (0.90-0.99)		0.85 (0.79-0.92)		0.81 (0.75-0.87)	
<b>Multivitamin use</b>								
No	0.85 (0.82-0.88)	<.001	0.90 (0.88-0.92)	.005	0.89 (0.86-0.92)	.005	0.83 (0.81-0.86)	.003
Yes	0.76 (0.73-0.79)		0.85 (0.83-0.88)		0.82 (0.79-0.86)		0.77 (0.74-0.80)	
<b>Aspirin use</b>								
No	0.80 (0.77-0.83)	.53	0.86 (0.84-0.88)	.02	0.83 (0.80-0.86)	.006	0.78 (0.76-0.81)	.04
Yes	0.81 (0.78-0.84)		0.89 (0.87-0.92)		0.89 (0.86-0.92)		0.82 (0.80-0.85)	
<b>Family history of myocardial infarction</b>								
No	0.82 (0.79-0.84)	.37	0.88 (0.86-0.90)	.34	0.86 (0.83-0.88)	.65	0.81 (0.79-0.83)	.89
Yes	0.78 (0.75-0.83)		0.88 (0.85-0.91)		0.88 (0.84-0.93)		0.80 (0.76-0.84)	
<b>Family history of diabetes</b>								
No	0.80 (0.78-0.83)	.17	0.87 (0.86-0.89)	.79	0.86 (0.83-0.89)	.39	0.80 (0.78-0.83)	.74
Yes	0.82 (0.78-0.86)		0.89 (0.86-0.92)		0.87 (0.83-0.91)		0.81 (0.77-0.84)	
<b>Family history of cancer</b>								
No	0.81 (0.78-0.83)	.73	0.87 (0.85-0.89)	.06	0.86 (0.84-0.89)	.78	0.80 (0.78-0.82)	.34
Yes	0.81 (0.77-0.86)		0.90 (0.87-0.94)		0.87 (0.82-0.92)		0.82 (0.78-0.86)	

Abbreviations: AHEI, Alternate Healthy Eating Index; AMED, Alternate Mediterranean Diet; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); HEI-2015, Healthy Eating Index 2015; HPDI, Healthful Plant-based Diet Index; HPFS, Health Professionals Follow-Up Study; NHS, Nurses' Health Study.

<sup>a</sup> Calculated per 25-percentile increment in 4 healthy eating scores (25 points for HEI-2015, 9 points for AMED, 18 points for HPDI, and 25 points for AHEI-2010). Multivariable analysis was adjusted for age, calendar year, race and ethnicity (NHS: Hispanic, non-Hispanic Black, non-Hispanic White, or other; HPFS, Black, White, or other), marriage status (married; divorced, separated, or single; or widowed), living status (alone or not alone), family history of myocardial infarction (yes or no), family history of diabetes (yes or no), family history of cancer (yes or no), menopausal status (pre- or

postmenopausal [never, past, or current menopausal hormone use]; NHS only), multivitamin use (yes or no), aspirin use (yes or no), total energy intake (quintile), smoking status (never, former, or current smoker [1-14, 15-24, or ≥25 cigarettes/d], alcohol drinking (0, 0.1-4.9, 5.0-14.9, 15.0-19.9, 20.0-29.9, or ≥30 g/d), physical activity (quintile), history of hypertension (yes or no), history of hypercholesterolemia (yes or no), and body mass index (<21, 21-24.9, 25-29.9, 30-34.9, or ≥35 [calculated as weight in kilograms divided by height in meters squared]), except the corresponding subgroup variates.

<sup>b</sup> Due to relatively small numbers, racial and ethnic minority groups were combined in the stratified analyses.

<sup>c</sup> Includes American Indian, Asian, Black, Hawaiian, and multiracial.

of death. Our findings support the recommendations of DGAs for multiple healthy eating patterns for all US individuals with diverse cultural and personal food traditions and preferences.

## ARTICLE INFORMATION

**Accepted for Publication:** November 10, 2022.

**Published Online:** January 9, 2023.

doi:10.1001/jamainternmed.2022.6117

**Author Affiliations:** Department of Nutrition and Food Hygiene, Hubei Key Laboratory of Food Nutrition and Safety, School of Public Health, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China (Shan); Ministry of Education Key Lab of Environment and Health, School of Public Health, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China (Shan); Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, Massachusetts (Shan, F. Wang, Li, Baden, Bhupathiraju, D. D. Wang, Sun, Rimm, L. Qi, Tabung, Giovannucci, Willett, Q. Qi, Hu); Department of Lifestyle Medicine, Osaka University Graduate School of Medicine, Suita, Japan (Baden, Sun); Channing Division of Network Medicine, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts (Bhupathiraju, D. D. Wang, Rimm, Tabung, Willett, Manson, Hu); Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, Massachusetts (Sun, Rimm, Giovannucci, Willett, Manson, Hu); Division of Preventive Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts (Rexrode, Manson); Division of Women's Health, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts (Rexrode); Department of Epidemiology, School of Public Health and Tropical Medicine, Tulane University, New Orleans, Louisiana (L. Qi); Division of Medical Oncology, Department of Internal Medicine, The Ohio State University College of Medicine and Comprehensive Cancer Center, Columbus (Tabung); Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Bronx, New York (Q. Qi).

**Author Contributions:** Drs Shan and F. Wang contributed equally. Drs Shan and Hu had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

**Concept and design:** Shan, Rimm, L. Qi, Giovannucci, Manson, Q. Qi, Hu.

**Acquisition, analysis, or interpretation of data:** Shan, F. Wang, Li, Baden, Bhupathiraju, D. Wang, Sun, Rexrode, Tabung, Giovannucci, Willett, Manson, Q. Qi, Hu.

**Drafting of the manuscript:** Shan.

**Critical revision of the manuscript for important intellectual content:** F. Wang, Li, Baden, Bhupathiraju, D. Wang, Sun, Rexrode, Rimm, L. Qi, Tabung, Giovannucci, Willett, Manson, Q. Qi, Hu.

**Statistical analysis:** Shan, F. Wang, Bhupathiraju, D. Wang, Willett.

**Obtained funding:** Rexrode, Willett, Q. Qi, Hu.

**Administrative, technical, or material support:** Baden, Willett, Manson, Hu.

**Supervision:** Bhupathiraju, L. Qi, Manson, Q. Qi, Hu.

**Conflict of Interest Disclosures:** Dr Baden reported receiving financial support from Kubara Honke Co, Ltd to her institution during the conduct

of the study and receiving grants from Grants-in-Aid for Scientific Research, the G-7 Scholarship Foundation, the Japan Diabetes Society, and the LOTTE Foundation outside the submitted work. Dr Bhupathiraju reported receiving personal fees from LayerIV. Dr Bhupathiraju reported being a consultant for LayerIV outside the submitted work. Dr Rimm reported receiving grants from and serving on the scientific advisory board for the US Department of Agriculture/US Highbush Blueberry Growers. Dr Manson reported receiving grants from the National Institutes of Health (NIH) during the conduct of the study and receiving grants from the NIH and Mars Edge outside the submitted work. Dr Q. Qi reported receiving grants from the National Heart, Lung, and Blood Institute (NHLBI) during the conduct of the study. No other disclosures were reported.

**Funding/Support:** This study was supported by grant R01HL060712 from the NHLBI (Drs Hu and Qi). The Nurses' Health Studies and Health Professional Follow-up Studies are supported by the grants UMI CA186107, PO1 CA87969, R01 CA49449, R01 HL034594, R01 HL088521, U01 CA176726, R01 CA67262, U01 CA167552, R01 HL35464, and U01 HL145386 from the NIH. Dr Qi is supported by grants K01HL129892 and R01 HL140976 from the NHLBI and grant R01 DK119268 and R01 DK120870 from the National Institute of Diabetes and Digestive and Kidney Diseases. Dr F. Wang is supported by postdoctoral fellowship grant 897161 from the American Heart Association.

**Role of the Funder/Sponsor:** The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

**Data Sharing Statement:** See [Supplement 2](#).

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