Alternative Dietary Indices Both Strongly Predict Risk of Chronic Disease[1–3]

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Abstract

The Healthy Eating Index-2005 (HEI-2005) measures adherence to the 2005 Dietary Guidelines for Americans, but the association between the HEI-2005 and risk of chronic disease is not known. The Alternative Healthy Eating Index (AHEI), which is based on foods and nutrients predictive of chronic disease risk, was associated inversely with chronic disease risk previously. We updated the AHEI, including additional dietary factors involved in the development of chronic disease, and assessed the associations between the AHEI-2010 and the HEI-2005 and risk of major chronic disease prospectively among 71,495 women from the Nurses' Health Study and 41,029 men from the Health Professionals Follow-Up Study who were free of chronic disease at baseline. During ≥24 y of follow-up, we documented 26,759 and 15,558 incident chronic diseases (cardiovascular disease, diabetes, cancer, or nontrauma death) among women and men, respectively. The RR (95% CI) of chronic disease comparing the highest with the lowest quintile was 0.84 (0.81, 0.87) for the HEI-2005 and 0.81 (0.77, 0.85) for the AHEI-2010. The AHEI-2010 and HEI-2005 were most strongly associated with coronary heart disease (CHD) and diabetes, and for both outcomes the AHEI-2010 was more strongly associated with risk than the HEI-2005 (*P*-difference = 0.002 and <0.001, respectively). The 2 indices were similarly associated with risk of stroke and cancer. These findings suggest that closer adherence to the 2005 Dietary Guidelines may lower risk of major chronic disease. However, the AHEI-2010, which included additional dietary information, was more strongly associated with chronic disease risk, particularly CHD and diabetes. J. Nutr. 142: 1009–1018, 2012.

Introduction

The Dietary Guidelines for Americans aim to provide science-based dietary advice that promotes good health and reduces major chronic diseases in the United States. The Dietary Guidelines are the most visible source of nutrition advice in the United States and the cornerstone of federal nutrition policy (1). Thus, it is imperative that they provide optimal guidance for preventing chronic disease. The Healthy Eating Index (HEI)[11], which quantified adherence to the 1995 Guidelines, was associated with only a modest reduction in risk of major chronic disease [fatal and nonfatal cardiovascular disease (CVD) or cancer and nontraumatic death] (2,3). In 2005, the 6th edition of the Dietary Guidelines and a new food guide, MyPyramid, were released, and the HEI-2005 quantifies adherence to these guidelines (4). Whether diets that are most consistent with the 2005 Dietary Guidelines are associated with lower risk of major chronic disease has not been evaluated.

The Alternate Healthy Eating Index (AHEI) was created in 2002 as an alternative to the HEI and was based on foods and nutrients predictive of chronic disease risk. Higher scores on the AHEI were strongly associated with lower risk of major chronic disease (5) as well as risk of CVD (5), diabetes (6), heart failure (7), colorectal (8) and estrogen-receptor-negative breast cancer (9), and total and cardiovascular mortality (10). Since the creation of the AHEI, substantial evidence has emerged to support a role of additional dietary factors in the development of chronic disease. Thus, we created the AHEI-2010, a new measure of diet quality that incorporates current scientific evidence on diet and health. In this analysis, we assessed the association between the AHEI-2010 and the HEI-2005 and risk of major chronic disease in the 2 large prospective cohorts in which the earlier scores had been evaluated.

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[3] Supplemental Tables 1–3 and Supplemental Methods are available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at http://jn.nutrition.org.
[11] Abbreviations used: AHEI, Alternate Healthy Eating Index; CHD, coronary heart disease; CVD, cardiovascular disease; HEI, Healthy Eating Index; HPFS, Health Professionals Follow-Up Study; NHS, Nurses' Health Study.
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TABLE 1 The AHEI-2010 scoring method and mean scores at baseline among women in the Nurses' Health Study (1984) and men in the Health Professionals Follow-Up Study (1986)[1]

Component	Criteria for minimum score (0)	Criteria for maximum score (10)	AHEI-2010 in women	AHEI-2010 in men
Vegetables,[2] *servings/d*	0	≥5	5.4 ± 2.4	5.6 ± 2.6
Fruit,[3] *servings/d*	0	≥4	3.4 ± 2.4	3.7 ± 2.6
Whole grains,[4] *g/d*	0		1.8 ± 1.7	2.4 ± 2.0
Women		75		
Men		90		
Sugar-sweetened beverages and fruit juice,[5] *servings/d*	≥1	0	3.0 ± 3.6	2.6 ± 3.5
Nuts and legumes,[6] *servings/d*	0	≥1	2.7 ± 2.5	4.1 ± 3.2
Red/processed meat,[7] *servings/d*	≥1.5	0	3.5 ± 3.1	3.1 ± 3.0
trans Fat,[8] *% of energy*	≥4	≤0.5	6.0 ± 1.7	7.8 ± 1.4
Long-chain (n-3) fats (EPA + DHA),[9] *mg/d*	0	250	6.2 ± 3.2	7.6 ± 3.1
PUFA,[10] *% of energy*	≤2	≥10	5.6 ± 2.0	4.7 ± 1.8
Sodium,[11] *mg/d*	Highest decile	Lowest decile	5.0 ± 3.2	5.0 ± 3.2
Alcohol,[12] d*rinks/d*			5.1 ± 3.1	5.8 ± 3.3
Women	≥2.5	0.5–1.5		
Men	≥3.5	0.5–2.0		
Total	0	110	47.6 ± 10.8	52.4 ± 11.5

[1] Values are means ± SD unless otherwise noted. Researchers are invited to re-create and use the AHEI-2010 score in their own data. AHEI, Alternate Healthy Eating Index.
[2] Vegetable consumption has been associated with lower risk of cardiovascular disease (CVD) (28,29) and some cancers (52,53). Green leafy vegetables in particular may lower risk of diabetes (30). All vegetables on the FFQ were included, except for potatoes (including French fries) because they are not associated with lower risk of chronic disease risk in epidemiologic studies (52,61) and are associated with increased risk of diabetes (62). We considered 5 servings/d as ideal, which reflects the upper range of current dietary guidelines and is consistent with intervention studies of intermediate CVD risk factors (63). One serving is 0.5 cup of vegetables or 1 cup of green leafy vegetables (1 cup = 236.59 g).
[3] Fruit consumption has been associated with lower risk of CVD (28,29) and some cancers (52,53). We included only whole fruit in our definition, because fruit juice is not associated with lower risk of CVD (51,61) or cancer (61) and may increase risk of diabetes (64). We considered 4 servings/d to be ideal, which is consistent with the upper range of current dietary guidelines. One serving is 1 medium piece of fruit or 0.5 cup of berries (1 cup = 236.59 g).
[4] Greater consumption of whole grains is associated with lower risk of CVD (32), diabetes (31), and colorectal cancer (65). Conversely, refined grains are not associated with lower risk and may increase risk of diabetes, coronary heart disease (CHD), and other chronic diseases (32,37,38). We used grams of whole grains, which accounts for the variability of the percentages of whole grain in various ''whole grain'' products (66). One serving of a 100% whole-grain product (i.e., 0.5 cup of oatmeal or brown rice) contains ~15–20 g of whole grains (per dry weight). We considered 75 g/d to be optimal (~5 servings/d) for women and 90 g/d (~6 servings/d) to be optimal for men on the basis of current guidelines for total grains.
[5] Intake of sugar-sweetened beverages, including soda and fruit drinks, is associated with increased risk of weight gain and obesity (67), CVD (35), and diabetes (34). We included intake of fruit juice in this category, given the positive association with risk of diabetes (64) and lack of beneficial effects on CVD (51) or cancer (61).The association with pancreatic cancer risk is not well established (68). We considered ≥1 serving/d to be the least optimal on the basis of the associations in the literature. One serving is 8 oz (1 oz = 28.35 g).
[6] Nuts, legumes, and vegetable protein (e.g., tofu) are important sources of protein and contain important constituents such as unsaturated fat, fiber, copper, magnesium, plant sterols, and other nutrients. Nuts and other vegetable proteins have been associated with lower risk of CVD, especially when used as a substitute for other protein sources, such as red meat (41). Nuts are also associated with lower risk of diabetes (42) and weight gain (69), whereas their relation to cancer is inconclusive (70). We considered 1 serving/d to be ideal on the basis of the AHEI recommendations and the current literature. One serving is 1 oz (1 oz = 28.35 g) of nuts or 1 tablespoon (15 mL) of peanut butter.
[7] Consumption of red meat and processed meats is associated with greater risk of CHD (48), especially when substituted for nuts, poultry, or fish (41). Red meat and/or processed meats are also associated with higher risk of stroke (45,46), diabetes (47), and colorectal and other cancers (52,55). Less than 1 serving/mo was considered to be ideal, with an upper limit of ≥1.5 servings/d. One serving is 4 oz of unprocessed meat or 1.5 oz of processed meat (1 oz = 28.35 g).
[8] *trans*-Isomers of fatty acids, formed by partial hydrogenation of vegetable oils to produce margarines and vegetable shortening, are associated with higher risk of CHD (71) and diabetes (72). Cutoffs are consistent with original AHEI cutoffs for *trans* fat.
[9] One serving of fish per week, specifically of species high in long-chain (n-3) fatty acids EPA + DHA, is strongly protective against fatal cardiac arrhythmias and sudden cardiac death (73) and may lower the incidence of other CVD (43,74). EPA + DHA were associated with lower risk of diabetes in some (40,44), but not all (75), studies, and the relation with cancer risk is unclear. Because of the strength and consistency of fish and EPA + DHA on cardiac arrhythmias and CVD, we included this nutrient in the AHEI-2010 score. The cutoff for optimal intake (250 mg/d) is ~2 4-oz servings of fish /wk, which is consistent with current guidelines (1 oz = 28.35 g).
[10] Replacing saturated fats with polyunsaturated fats leads to positive changes in lipid profiles (63), is associated with a lower risk of CHD (36), and may lower risk of type 2 diabetes (76). Furthermore, a low-fat diet had no beneficial effects on CVD risk factors, lipid profile, or blood pressure and did not reduce the risk of CVD, breast cancer, colon cancer, or total mortality (77–79). We gave the highest score to individuals with ≥10% of total energy intake from PUFA on the basis of current guidelines from the USDA and the AHA (50,80). PUFA does not include EPA or DHA intake.
[11] High sodium intake has been associated with higher blood pressure (81), and salt-preserved foods are associated with greater risk of stomach cancer (52), CVD (54), and total mortality (82). Furthermore, sodium-reduced diets significantly lowered blood pressure (83) and CVD risk in clinical trials (84). Large reductions in sodium intake, to levels recommended by the USDA (60), may prevent a substantial number of new cases of CHD (33). The cutoffs for sodium were based on deciles of distribution in the population, due to lack of brand specificity in the FFQ to accurately estimate absolute intake. Values in lowest decile were ≤1112 mg/d in women and ≤1612 mg/d in men and in highest decile were ≥3337 mg/d in women and ≥5271 mg/d in men at baseline.
[12] In moderation, alcohol may be consumed as a part of an overall healthy diet. Moderate alcohol consumption has been associated with lower risk of CHD (85), dementia (86), diabetes (87), and all-cause and CVD mortality (88). However, in heavier quantities, alcohol increases the risk of certain cancers (52) and has other health and social implications such as alcoholism and alcohol-related injuries (89). Furthermore, many adults choose not to drink for various reasons. Thus, we assigned the highest score to moderate, and the worst score to heavy, alcohol consumers. Nondrinkers received a score of 2.5. We used gender-specific cutoffs, because the health effects of alcohol are seen at lower quantities in women than in men. One drink is 4 oz of wine, 12 oz of beer, or 1.5 oz of liquor (1 oz = 28.35 g).

Participants and Methods

Study population. In 1976, 121,700 female nurses aged 30–55 y enrolled in the Nurses' Health Study (NHS) (11). In 1984, 81,757 of these women completed an extensive FFQ. The Health Professionals Follow-Up Study (HPFS) is a prospective cohort of 51,529 U.S. men, aged 40–75 y, who returned a questionnaire about diet and medical history in 1986 (12). Participants of both cohorts provided information on diet lifestyle factors, medical history, and newly diagnosed diseases through self-administered mailed questionnaires at baseline and updated every 2–4 y.

We excluded women and men with previously diagnosed CVD (myocardial infarction, angina, stroke, transient ischemic attack, and revascularization), diabetes, and cancer at baseline. We also excluded

TABLE 2 RR (95% CI) of chronic disease by quintile of the HEI-2005 among women in the Nurses' Health Study (1984–2008) and men in the Health Professionals Follow-Up Study (1986–2008)[1]

	HEI-2005					
	Q1	Q2	Q3	Q4	Q5	*P*-linear trend[2]
Major chronic disease						
Women						
Range	<53.5	53.5–60.0	60.1–65.3	65.4–71.3	>71.3	
Median	48.6	57.1	62.7	68.2	75.4	
Cases, *n*	5901	5287	5224	5166	5181	
Age-adjusted	1.0 (ref)	0.84 (0.81, 0.88)	0.80 (0.77, 0.83)	0.75 (0.72, 0.78)	0.68 (0.66, 0.71)	<0.001
Multivariate-adjusted[3]	1.0 (ref)	0.91 (0.88, 0.95)	0.90 (0.87, 0.94)	0.88 (0.84, 0.91)	0.84 (0.80, 0.87)	<0.001
Men						
Range	<53.6	52.6–60.0	60.0–66.3	66.3–73.2	>73.2	
Median	47.0	56.6	63.1	69.5	77.7	
Cases, *n*	3373	3178	3052	2990	2965	
Age-adjusted	1.0 (ref)	0.90 (0.85, 0.94)	0.83 (0.79, 0.87)	0.80 (0.76, 0.84)	0.74 (0.70, 0.78)	<0.001
Multivariate-adjusted	1.0 (ref)	0.95 (0.90,1.00)	0.90 (0.85, 0.95)	0.89 (0.85, 0.94)	0.84 (0.80, 0.89)	<0.001
Pooled						
Multivariate-adjusted	1.0 (ref)	0.93 (0.89, 0.96)	0.90 (0.87, 0.93)	0.88 (0.85, 0.91)	0.84 (0.81, 0.87)	<0.001
Cardiovascular disease						
Women						
Cases, *n*	1168	980	932	896	892	
Multivariate-adjusted	1.0 (ref)	0.89 (0.82, 0.97)	0.87 (0.79, 0.95)	0.81 (0.74, 0.89)	0.75 (0.68, 0.82)	<0.001
Men						
Cases, *n*	1082	1057	1019	982	962	
Multivariate-adjusted	1.0 (ref)	0.97 (0.89, 1.06)	0.91 (0.83, 1.00)	0.89 (0.81, 0.98)	0.84 (0.76, 0.92)	<0.001
Pooled						
Multivariate-adjusted	1.0 (ref)	0.93 (0.85, 1.02)	0.89 (0.84, 0.95)	0.85 (0.78, 0.93)	0.79 (0.71, 0.88)	<0.001[4]
Coronary heart disease						
Women						
Cases, *n*	469	376	375	337	329	
Multivariate-adjusted	1.0 (ref)	0.88 (0.77, 1.02)	0.92 (0.80, 1.06)	0.81 (0.70, 0.94)	0.75 (0.64, 0.87)	<0.001
Men						
Cases, *n*	548	495	472	475	433	
Multivariate-adjusted	1.0 (ref)	0.93 (0.82, 1.05)	0.86 (0.75, 0.98)	0.90 (0.79, 1.03)	0.77 (0.67, 0.89)	0.02
Pooled						
Multivariate-adjusted	1.0 (ref)	0.91 (0.83, 0.99)	0.89 (0.81, 0.98)	0.86 (0.78, 0.95)	0.76 (0.68, 0.84)	<0.001
Stroke						
Women						
Cases, *n*	380	345	353	332	351	
Multivariate-adjusted	1.0 (ref)	0.93 (0.80, 1.08)	0.96 (0.82, 1.11)	0.86 (0.74, 1.01)	0.82 (0.70, 0.96)	0.01
Men						
Cases, *n*	218	218	200	186	189	
Multivariate-adjusted	1.0 (ref)	1.02 (0.84, 1.24)	0.91 (0.74, 1.04)	0.84 (0.68, 1.04)	0.82 (0.66, 1.02)	0.02
Pooled						
Multivariate-adjusted	1.0 (ref)	0.96 (0.86, 1.09)	0.94 (0.83, 1.06)	0.86 (0.75, 0.97)	0.82 (0.72, 0.93)	<0.001
Diabetes						
Women						
Cases, *n*	1367	1302	1171	1064	976	
Multivariate-adjusted	1.0 (ref)	0.97 (0.90, 1.05)	0.91 (0.84, 0.99)	0.84 (0.77, 0.92)	0.83 (0.76, 0.90)	<0.001
Men						
Cases, *n*	573	540	494	462	388	
Multivariate-adjusted	1.0 (ref)	0.96 (0.85, 1.08)	0.91 (0.80, 1.03)	0.89 (0.78, 1.01)	0.82 (0.71, 0.94)	0.003
Pooled						
Multivariate-adjusted	1.0 (ref)	0.97 (0.91, 1.03)	0.91 (0.85, 0.98)	0.86 (0.80, 0.92)	0.82 (0.76, 0.89)	<0.001
Cancer						
Women						
Cases, *n*	2510	2352	2387	2530	2590	
Multivariate-adjusted	1.0 (ref)	0.93 (0.88, 0.99)	0.93 (0.88, 0.98)	0.95 (0.90, 1.01)	0.93 (0.87, 0.98)	0.04

(Continued)

TABLE 2 *Continued*

	HEI-2005					
	Q1	Q2	Q3	Q4	Q5	*P*-linear trend[2]
Men						
Cases, *n*	1204	1067	1063	1113	1136	
Multivariate-adjusted	1.0 (ref)	0.87 (0.80, 0.95)	0.86 (0.79, 0.93)	0.89 (0.81, 0.97)	0.86 (0.79, 0.94)	0.003
Pooled						
Multivariate-adjusted	1.0 (ref)	0.91 (0.85, 0.97)	0.90 (0.83, 0.97)	0.93 (0.86, 0.99)	0.90 (0.84, 0.96)	0.001

[1] HEI, Healthy Eating Index; Q, quintile; ref, reference.
[2] Test for linear trend calculated by assigning the median value of diet score in each quintile and modeling this as a continuous variable in regression models.
[3] Multivariate Cox proportional hazards models adjusted for age (in mo), energy (kcal/d, continuous), smoking status (5 categories), BMI (8 categories), aspirin (0, 1–6, ≥7 d/wk), physical activity (5 categories), vitamin E supplementation, family history of myocardial infarction, and family history of colon cancer; in the analysis in women, models adjusted for family history of breast cancer, menopausal status, and use of hormone therapy. All models were adjusted for history of hypertension and history of hypercholesterolemia, except where cancer was the only outcome.
[4] *P*-heterogeneity between studies <0.05 based on the Cochran Q statistic.

participants with invalid FFQ data (13), leaving 71,495 women and 41,029 men for analysis. The institutional review boards at the Harvard School of Public Health and Brigham and Women's Hospital approved the study protocol.

Dietary assessment. We used a previously validated FFQ (14–16) to collect dietary data in the NHS in 1984 and 1986 and subsequently every 4 y through 2006. In the HPFS, dietary information has been collected every 4 y, from 1986 to 2006. For each food item, a commonly used portion size was specified and participants were asked how often, on average, he or she had consumed that quantity over the past year. We calculated nutrient intake by multiplying the frequency of intake for each food by its nutrient content and summing nutrient contributions across all food items (13).

The HEI-2005. The HEI-2005 was based on criteria in the Technical Report of the Healthy Eating Index-2005 (4) and includes 12 components that represent the major food groups found in MyPyramid and recommendations from the 2005 Dietary Guidelines for Americans (**Supplemental Table 1**). Components in the HEI-2005 were energy-adjusted on a density basis (per 1000 kcal/d).

We modified the scoring for the sodium component from the published HEI-2005 due to the lack of brand specificity and information about discretionary use of salt on some questionnaires. As done previously (2,3), we divided the participants into 11 equal groups on the basis of the distribution of reported sodium intake (mg/d) and assigned corresponding scores of 0–10 (higher score for less sodium consumed).

AHEI- 2010. The AHEI-2010 was based on a comprehensive review of the relevant literature and discussions with other nutrition researchers to identify foods and nutrients that have been associated consistently with lower risk of chronic disease in clinical and epidemiologic investigations, including information from the original AHEI (5). The rationale for variable selection and scoring criteria for the AHEI-2010 is described in **Table 1**, and all variables and scoring decisions for the AHEI-2010 were determined a priori. All AHEI-2010 components were scored from 0 (worst) to 10 (best), and the total AHEI-2010 score ranged from 0 (nonadherence) to 110 (perfect adherence).

Outcome definition. We included incident CVD, diabetes, cancer, and nontraumatic death in our endpoint of selected major chronic disease. CVD, cancer, and diabetes are the first, second, and seventh leading causes of death in the United States, respectively (17). We also included diabetes because of its high prevalence in the United States (8.3% of adults) and because it is a leading cause of CVD and other health complications (18).When a participant reported an incident event, we requested permission to review medical records, which were reviewed by study investigators blinded to the participant's risk factor status.

We defined CVD as coronary heart disease (CHD); nonfatal myocardial infarction and fatal CHD, stroke, or angina. Myocardial infarction was defined according to WHO criteria and cardiac-specific troponin levels (19). Strokes were confirmed by using the National Survey of Stroke criteria, which requirie neurological deficit of rapid or sudden onset lasting ≥24 h or until death (20). Angina was confirmed when a participant reported "angina pectoris" on the questionnaire and met one of the following criteria: ≥70% occlusion, coronary artery bypass graft; percutaneous transluminal coronary angioplasty; or coronary stenting.

Type 2 diabetes was defined as self-reported diabetes confirmed by a validated supplementary questionnaire (21). We used criteria proposed by the National Diabetes Data Group (22) (before 1998) and the American Diabetes Association criteria (after 1998). We included all cancers, except for those with relatively low mortality [nonmelanoma skin cancer; low-grade, organ-confined prostate cancer (stage A or B and Gleason grade <7) and in situ breast cancer].

We included deaths, except for those resulting from external causes (e.g., injuries and suicides). Deaths were reported by next of kin, postal authorities, or through the National Death Index (23). We attempted to confirm each cause of death by reviewing medical records or autopsy reports.

Statistical analysis. Each participant contributed follow-up time from the return of the baseline questionnaire until the date of diagnosis of the first event (CHD, stroke, angina, diabetes, or cancer), date of death, or end of follow-up (June 2008 in women, February 2008 in men). Cases were excluded from subsequent follow-up; thus, each person contributed only one diagnosed endpoint to the analysis.

We calculated the cumulative mean of the diet scores to optimize the use of repeated dietary questionnaires. Because changes in diet after the development of intermediate endpoints (hypercholesterolemia, hypertension, and transient ischemic attacks) may confound the associations between diet and disease, we stopped updating dietary information after these diagnoses.

We calculated the HR for disease by quintiles of the dietary scores using multivariate Cox proportional hazard models as an estimate of the RR, with adjustment for potential confounders (see Table 2 for full list of covariates). A test for linear trend across quintiles was performed by assigning the median values to each quintile and modeled as a single continuous variable. All variables, except for baseline hypertension and hypercholesterolemia, were included in models as time-varying covariates. The summary risk estimate was calculated by pooling the RR from the cohorts with the use of a random-effects model (24). Between-study heterogeneity was evaluated by using the Cochran Q statistic.

We formally compared the associations of the HEI-2005 and AHEI-2010 with disease risk, by including both diet scores in the model simultaneously and using a Wald test (see **Supplemental Methods**).

In addition, we examined the independent associations between the individual components of each diet score and risk of major chronic disease. Finally, we estimated the associations between the original HEI and the AHEI (5) and risk of chronic disease by using the same follow-up and definition of major chronic disease (including diabetes and angina). All analyses were carried out by using SAS version 9.2 (SAS Institute, Inc.), and a *P* value of <0.05 was considered significant.

TABLE 3 RR (95% CI) of chronic disease by quintile of the AHEI-2010 among women in the Nurses' Health Study (1984–2008) and men in the Health Professionals Follow-Up Study (1986–2008)[1]

	AHEI-2010					
	Q1	Q2	Q3	Q4	Q5	*P*-linear trend[2]
Major chronic disease						
Women						
Range	<40.3	40.3–46.0	46.1–51.3	51.4–57.8	>57.8	
Median	36.2	43.4	48.6	54.3	62.7	
Cases, *n*	5879	5414	5333	5092	5041	
Age-adjusted	1.0 (ref)	0.85 (0.82, 0.88)	0.80 (0.77, 0.83)	0.73 (0.70, 0.76)	0.67 (0.65, 0.70)	<0.001
Multivariate-adjusted[3]	1.0 (ref)	0.90 (0.87, 0.94)	0.87 (0.84, 0.90)	0.82 (0.79, 0.85)	0.79 (0.76, 0.82)	<0.001
Men						
Range	<42.6	42.6–49.2	49.3–55.2	55.3–62.3	>62.3	
Median	38.0	46.1	52.2	58.4	67.6	
Cases, *n*	3210	3137	3119	3077	3016	
Age-adjusted	1.0 (ref)	0.92 (0.87, 0.96)	0.86 (0.82, 0.90)	0.81 (0.77, 0.85)	0.74 (0.70, 0.78)	<0.001
Multivariate-adjusted	1.0 (ref)	0.96 (0.91, 1.00)	0.91 (0.86, 0.96)	0.88 (0.83, 0.93)	0.83 (0.79, 0.87)	<0.001
Pooled						
Multivariate-adjusted	1.0 (ref)	0.93 (0.88, 0.98)	0.89 (0.85, 0.92)	0.85 (0.79, 0.91)[4]	0.81 (0.77, 0.85)	<0.001[4]
Cardiovascular disease						
Women						
Cases, *n*	1101	1010	938	915	904	
Multivariate-adjusted	1.0 (ref)	0.91 (0.84, 0.99)	0.82 (0.75, 0.89)	0.79 (0.72, 0.86)	0.74 (0.67, 0.81)	<0.001
Men						
Cases, *n*	1062	1062	1029	989	960	
Multivariate-adjusted	1.0 (ref)	0.96 (0.88, 1.05)	0.89 (0.81, 0.97)	0.84 (0.77, 0.92)	0.78 (0.71, 0.86)	<0.001
Pooled						
Multivariate-adjusted	1.0 (ref)	0.94 (0.88, 1.00)	0.85 (0.79, 0.93)	0.81 (0.76, 0.87)	0.76 (0.71, 0.81)	<0.001
Coronary heart disease						
Women						
Cases, *n*	453	406	351	343	333	
Multivariate-adjusted	1.0 (ref)	0.89 (0.78, 1.02)	0.74 (0.64, 0.86)	0.72 (0.62, 0.84)	0.67 (0.58, 0.78)	<0.001
Men						
Cases, *n*	522	548	465	455	433	
Multivariate-adjusted	1.0 (ref)	1.01 (0.89, 1.14)	0.81 (0.71, 0.92)	0.78 (0.68, 0.89)	0.70 (0.61, 0.80)	<0.001
Pooled						
Multivariate-adjusted	1.0 (ref)	0.50 (0.85, 1.05)	0.78 (0.71, 0.86)	0.75 (0.68, 0.83)	0.69 (0.62, 0.76)	<0.001
Stroke						
Women						
Cases, *n*	361	346	372	331	351	
Multivariate-adjusted	1.0 (ref)	0.92 (0.79, 1.07)	0.95 (0.82, 1.11)	0.83 (0.71, 0.97)	0.83 (0.71, 0.97)	0.01
Men						
Cases, *n*	215	200	201	203	192	
Multivariate-adjusted	1.0 (ref)	0.90 (0.74, 1.11)	0.86 (0.70, 1.05)	0.85 (0.70, 1.04)	0.76 (0.62, 0.94)	0.01
Pooled						
Multivariate-adjusted	1.0 (ref)	0.92 (0.81, 1.03)	0.92 (0.82, 1.03)	0.84 (0.74, 0.95)	0.80 (0.71, 0.91)	<0.001
Diabetes						
Women						
Cases, *n*	1569	1312	1171	1006	822	
Multivariate-adjusted	1.0 (ref)	0.88 (0.81, 0.94)	0.81 (0.75, 0.87)	0.74 (0.68, 0.80)	0.65 (0.59, 0.71)	<0.001
Men						
Cases, *n*	598	527	491	464	397	
Multivariate-adjusted	1.0 (ref)	0.89 (0.78, 1.00)	0.85 (0.75, 0.96)	0.84 (0.74, 0.95)	0.72 (0.63, 0.82)	<0.001
Pooled						
Multivariate-adjusted	1.0 (ref)	0.88 (0.82, 0.94)	0.82 (0.77, 0.87)	0.78 (0.69, 0.88)	0.67 (0.61, 0.74)	<0.001[4]
Cancer						
Women						
Cases, *n*	2412	2389	2512	2429	2627	
Multivariate-adjusted	1.0 (ref)	0.94 (0.89, 1.00)	0.96 (0.91, 1.02)	0.90 (0.85, 0.95)	0.93 (0.88, 0.99)	0.01

(Continued)

TABLE 3 *Continued*

	AHEI-2010					
	Q1	Q2	Q3	Q4	Q5	*P*-linear trend[2]
Men						
Cases, *n*	1066	1079	1115	1118	1205	
Multivariate-adjusted	1.0 (ref)	0.97 (0.89, 1.05)	0.96 (0.88, 1.04)	0.93 (0.85, 1.01)	0.94 (0.87, 1.03)	0.13
Pooled						
Multivariate-adjusted	1.0 (ref)	0.95 (0.91, 1.00)	0.96 (0.91, 1.01)	0.91 (0.87, 0.95)	0.94 (0.89, 0.98)	0.003

[1] AHEI, Alternative Healthy Eating Index; Q, quintile; ref, reference.
[2] Test for linear trend calculated by assigning the median value of diet score in each quintile and modeling this as a continuous variable in regression models.
[3] Multivariate Cox proportional hazards models adjusted for age (in mo), energy (kcal/d, continuous), smoking status (5 categories), BMI (8 categories),aspirin (0, 1–6, ≥7 d/wk), physical activity (5 categories), vitamin E supplementation, family history of myocardial infarction, and family history of colon cancer; in the analysis in women, models adjusted for family history of breast cancer, menopausal status, and use of hormone therapy. All models were adjusted for history of hypertension and history of hypercholesterolemia, except where cancer was the only outcome.
[4] *P*-heterogeneity between studies < 0.05 based on the Cochran Q statistic.

Results

Among women in the NHS, we documented 26,759 incident chronic disease events (4868 CVD, 12,369 cancer, 5880 diabetes, and 3642 nontraumatic deaths) over 24 y of follow-up. Among men, we documented 15,558 chronic disease events (5102 CVD, 5583 cancers, 2457 diabetes, and 2416 nontraumatic deaths) over 22 y of follow-up. The correlation between HEI-2005 and AHEI-2010 scores was high, because the scores shared several important components such as a high intake of vegetables, whole fruit, and whole grains, and a low intake of sodium ($r = 0.65$, $P < 0.001$ in women; $r = 0.68$, $P < 0.001$ in men).

For both diet scores, participants with greater adherence tended to have lower BMI, to exercise more, and were less likely to be a current smoker;women were more likely to use hormone therapy (**Supplemental Table 2**).

Risk of major chronic disease. The HEI-2005 was inversely associated with risk of major chronic disease among women and men (*P*-trend < 0.001) in age-adjusted models (**Table 2**). Although further adjustment for confounders attenuated the associations, the HEI-2005 remained significantly associated with lower risk (*P*-trend < 0.001). The pooled RR for major chronic disease comparing the highest with the lowest quintile of the original HEI was similar in magnitude [RR: 0.85 (95% CI: 0.82, 0.88)] (data not shown). The correlation between the HEI and HEI-2005 was 0.50 ($P < 0.001$) in women and 0.65 ($P < 0.001$) in men. The HEI-2005 was significantly inversely associated with risk of each of the major chronic diseases individually, including total CVD, CHD, stroke, diabetes, and total cancer, among both women and men (Table 2).

The AHEI-2010 was associated inversely with risk of major chronic disease in both women and men in age-adjusted and multivariate models (*P*-trend < 0.001 for both) (**Table 3**). The AHEI-2010 was strongly correlated with the AHEI ($r = 0.67$ in women and 0.77 in men, $P < 0.001$). For men and women combined, the RR of major chronic disease comparing the highest with the lowest quintile was 0.81 (95% CI: 0.77, 0.85) for both the AHEI and the AHEI-2010.

Higher AHEI-2010 scores were inversely associated with risk of CVD (*P*-trend < 0.001), and the AHEI-2010 was more strongly associated with risk of CHD than stroke (Table 3). The AHEI-2010 was inversely associated with risk of diabetes (Table 3). The AHEI-2010 was inversely associated with risk of total cancer in women (*P*-trend = 0.01) but not in men (*P*-trend = 0.13). However, in pooled analysis, the AHEI-2010 was inversely associated with cancer (*P*-trend = 0.003) (Table 3).

Comparison of the HEI-2005 and AHEI-201. When included in the same model, the AHEI-2010 was more strongly associated with the risk of major chronic disease than the HEI-2005 (*P*-difference in diet scores < 0.001) (**Table 4**). The association between the AHEI-2010 and risk of major chronic disease was minimally attenuated when the HEI-2005 was included in the model. For the HEI-2005, the RR for chronic disease was attenuated, although remained significant after adjustment for the AHEI-2010.

The AHEI-2010 was more strongly associated with risk of CHD (*P*-difference between diet scores = 0.002) and diabetes (*P*-difference between diet scores < 0.001) (Table 4). The association between the AHEI-2010 and risk of CHD and diabetes was not attenuated and remained significant after adjustment for the HEI-2005. Conversely, the HEI-2005 was not significantly associated with risk of CHD or diabetes after adjustment for the AHEI-2010 (Table 4). For both stroke and cancer, we did not detect significance differences in association between the diet scores (*P*-difference in diet scores: 0.87 for stroke and 0.23 for cancer).

Individual components of the HEI-2005 and AHEI-2010 and risk of disease. The components of the HEI-2005 that were independently associated with lower risk of major chronic disease were dark-green and orange vegetables, whole fruit, and whole grains and to a lesser extent total grains, milk, vegetable oils, and a low intake of sodium (**Supplemental Table 3**). For the AHEI-2010, a higher intake of whole grains, nuts, and alcoholic beverages and a lower intake of sugar-sweetened beverages and red/processed meats were associated with lower risk of major chronic disease.

For the HEI-2005, dark-green and orange vegetables, whole grains, and energy from solid fat, alcohol, and added sugar were significantly associated with lower risk of CHD and diabetes. The inverse association for the solid fat, alcohol, and added sugar component was driven by alcohol intake. In addition, a high intake of whole fruit, milk, and oils and a low intake of sodium and saturated fat were associated with risk of diabetes. Vegetable oils were associated with risk of CHD among women only. For the AHEI-2010, whole grains and alcoholic beverages were inversely associated, and red and processed meats were positively associated with risk of CHD and diabetes; in addition, sugar-sweetened beverages, sodium, and EPA + DHA were also associated with greater risk of diabetes.

Discussion

In these 2 large prospective cohorts, women and men whose diets most closely matched the goals of the 2005 Dietary

TABLE 4 Pooled RR (95% CI) of chronic disease by quintile of HEI-2005 and AHEI-2010, adjusted for the other score, among women in the Nurses' Health Study (1984–2008) and men in the Health Professionals Follow-Up Study (1986–2008)[1]

	Dietary score						
	Q1	Q2	Q3	Q4	Q5	*P*-linear trend[2]	*P*-similar effects of diet scores[3]
Major chronic disease							
HEI-2005[4]	1.0 (ref)	0.96 (0.93, 0.99)	0.96 (0.93, 0.99)	0.96 (0.93, 0.99)	0.94 (0.90, 0.98)	0.003	<0.001
AHEI-2010[5]	1.0 (ref)	0.94 (0.88, 0.99)	0.90 (0.86, 0.95)	0.87 (0.80, 0.94)[6]	0.83 (0.78, 0.90)	<0.001[6]	
Cardiovascular disease							
HEI-2005	1.0 (ref)	0.96 (0.89, 1.04)	0.96 (0.89, 1.03)	0.95 (0.86, 1.04)	0.91 (0.80, 1.04)	0.17	0.06
AHEI-2010	1.0 (ref)	0.95 (0.89, 1.01)	0.87 (0.81, 0.93)	0.84 (0.78, 0.90)	0.80 (0.74, 0.86)	<0.001	
Coronary heart disease							
HEI-2005	1.0 (ref)	0.97 (0.88, 1.07)	1.01 (0.91, 1.12)	1.03 (0.92, 1.16)	0.97 (0.86, 1.10)	0.99	0.002
AHEI-2010	1.0 (ref)	0.95 (0.85, 1.06)	0.78 (0.70, 0.86)	0.75 (0.67, 0.84)	0.69 (0.61, 0.78)	<0.001	
Stroke							
HEI-2005	1.0 (ref)	0.99 (0.88, 1.12)	0.98 (0.86, 1.12)	0.91 (0.79, 1.05)	0.90 (0.77, 1.05)	0.12	0.87
AHEI-2010	1.0 (ref)	0.93 (0.82, 1.05)	0.94 (0.83, 1.07)	0.87 (0.76, 1.00)	0.86 (0.74, 1.00)	0.03	
Diabetes							
HEI-2005	1.0 (ref)	1.03 (0.97, 1.11)	1.03 (0.95, 1.10)	1.02 (0.94, 1.10)	1.06 (0.96, 1.16)	0.38	<0.001
AHEI-2010	1.0 (ref)	0.87 (0.82, 0.93)	0.81 (0.75, 0.87)	0.77 (0.67, 0.89)	0.66 (0.57, 0.76)	<0.001[6]	
Cancer							
HEI-2005	1.0 (ref)	0.91 (0.84, 0.99)	0.91 (0.82, 1.01)	0.94 (0.84, 1.05)	0.91 (0.81, 1.03)	0.16	0.23
AHEI-2010	1.0 (ref)	0.97 (0.92, 1.02)	0.98 (0.93, 1.03)	0.95 (0.86, 1.03)	0.97 (0.90, 1.05)	0.10	

[1] Values were estimated from Cox proportional hazards models adjusted for age (in mo), energy (kcal/d, continuous), smoking status (5 categories), BMI (8 categories), aspirin (0, 1–6, ≥7 d/wk), physical activity (5 categories), vitamin E supplementation, family history of myocardial infarction, and family history of colon cancer; in the analysis in women, models additionally adjusted for family history of breast cancer, menopausal status, and use of hormone therapy. All models were adjusted for history of hypertension and history of hypercholesterolemia, except where cancer was the only outcome. The risk estimates from each cohort were pooled by using the DerSimonian and Laird random-effects model. AHEI, Alternative Healthy Eating Index; HEI, Healthy Eating Index; Q, quintile; ref, reference.
[2] Test for linear trend calculated by assigning the median value of diet score in each quintile and modeling this as a continuous variable in regression models.
[3] *P*-value based on the Wald test evaluating the hypothesis that the β-coefficient in quintile 5 for the AHEI-2010 equals the β-coefficient in quintile 5 for the HEI-2005.
[4] Additionally adjusted for the AHEI-2010 (quintiles).
[5] Additionally adjusted for the HEI-2005 (quintiles).
[6] *P*-heterogeneity between studies <0.05 based on the Cochran Q statistic.

Guidelines, as assessed by the HEI-2005, had a 16% lower risk of major chronic disease, which was attributable to a 23% lower risk of CHD and 18% lower risk of diabetes. Higher scores on an alternative dietary index, the AHEI-2010, were associated with a 19% lower risk of chronic disease, a 31% lower risk of CHD, and a 33% lower risk of diabetes. When modeled simultaneously, the AHEI-2010 was associated more strongly with risk of major chronic disease, CHD, and diabetes than was the HEI-2005. There were no significant differences in the association between the AHEI-2010 and HEI-2005 and risk of either stroke or cancer.

The inverse association between the HEI-2005 and CHD and diabetes is consistent with previous studies in which greater adherence to the 2005 Dietary Guidelines was associated with lower prevalence of the metabolic syndrome (25), reduced atherosclerotic progression (26), and lower insulin resistance (among women only) (27). The HEI-2005 was not associated with lower risk of CHD and diabetes after adjustment for the AHEI-2010; however, the inverse association between the AHEI-2010 and risk remained strong after adjustment for the HEI-2005. Although there are common and beneficial components of both diet scores—with their emphasis on increasing vegetables (28–30), fruit (28,29), and whole grains (31,32) and reducing sodium (33), added sugar (34,35), and saturated fat (36)—the AHEI-2010 captures additional information on diet quality that may lower the risk of metabolic diseases further. For example, the AHEI-2010 emphasizes intake of whole, not total, grains; refined grains are not associated with lower risk of metabolic diseases and may increase risk (37,38). The AHEI-2010 provides separate recommendations for protein sources, given their different effects on health; nuts, legumes, and fish, specifically those high in EPA + DHA, are associated with lower risk of metabolic diseases (39–44), whereas red and processed meats are associated with greater risk (41,45–48). The AHEI-2010 promotes a high intake of PUFA, at levels consistent with current recommendations from the American Heart Association (49,50). Finally, the AHEI-2010 provides quantitative guidance for reduction in sugar-sweetened beverages, separate from other discretionary calories, given their positive association with risk of CHD (35,51) and diabetes (34). One or more of these components may contribute to the additional benefits of the AHEI-2010 on CHD and diabetes risk.

Many of the components of the diet scores were included because of their associations with CHD and diabetes specifically, because fewer optimal dietary factors have been established for the prevention of stroke and cancer. Yet, the AHEI-2010 and HEI-2005 were both associated with lower risk of cancer and stroke as well. Both diet scores emphasize high intakes of fruit, vegetables, and whole grains and low sodium intake, because these have been associated with lower risk of cancer (52,53) and/or stroke (29,32,54). In addition, the AHEI-2010 emphasizes a low intake of red and processed meats, which is a risk factor for certain cancers (52,55), whereas dairy foods, a component of the HEI-2005, may lower risk of colon cancer (56).

Total cancer is a heterogeneous endpoint, and dietary factors may play a stronger role in the etiology of certain cancers. For example, the HEI-2005 was associated with lower risk of colorectal (8,57), but not endometrial (58), cancer, whereas the AHEI was associated with lower risk of colorectal cancer (8) and estrogen-receptor-negative, but not estrogen-receptor-positive, breast cancer (9). Thus, future studies should assess the association between the HEI-2005 and AHEI-2010 diet scores and other organ-specific cancers.

Greater adherence to the 2005 Dietary Guidelines predicted lower risk of chronic disease to a similar degree as adherence to the prior guidelines, as assessed by the HEI. In the current analysis, the magnitude of association between the original HEI and risk of major chronic disease (RR for quintile 5 vs. quintile 1: 0.85) was consistent with the prior association observed for major chronic disease risk (without diabetes) in the HPFS after 8 y of follow-up (RR for quintile 5 vs. quintile 1: 0.89) (2). The inclusion of diabetes in the major chronic disease endpoint increased the proportion of metabolic diseases and may have strengthened the association among women, which was null previously (3). The association between the AHEI and the AHEI-2010 and risk of major chronic disease was also similar in magnitude. Although some components differ, the AHEI and AHEI-2010 captured a similar dietary pattern, as was evident in the strong correlations between the diet scores.

The Dietary Guidelines aim to provide a dietary pattern that, if followed, could lower major chronic disease. From an etiologic standpoint, it may not be appropriate to pool all chronic diseases. However, from a public health perspective, the prevention of all chronic diseases is important. Therefore, it is necessary to assess dietary scores on risk of total chronic disease, to identify the most scientifically sound dietary recommendations.

We included components in the AHEI-2010 on the basis of diet-disease relationships in the current literature, including reports from these cohorts. However, associations between individual components of the AHEI-2010 and chronic disease have been observed in many other populations, and the AHEI, which was derived in a similar fashion, was strongly predictive of CVD risk in several independent populations (7,10). Nevertheless, further testing of the AHEI-2010 in independent study populations is warranted.

The dietary quality within these cohorts of mostly white, well-educated health professionals may not be representative of the dietary quality in the United States. The mean HEI-2005 in these cohorts (mean: 62.3 in women; 62.7 in men) is slightly higher compared with the HEI-2005 in the general U.S. population (mean score = 57.5) (59). In addition, these analyses were based on the 2005 Dietary Guidelines, which were recently updated (60). The HEI-2010 has not been released, and thus we cannot assess adherence to the most recent guidelines. The impact of adherence to the new guidelines should be evaluated in future studies. Finally, many lifestyle factors play an important role in the development of chronic disease and may confound the association between diet quality and disease risk. Although we controlled for these factors in our analysis, residual confounding remains possible. Importantly, the educational and occupational homogeneity of this population minimizes variation in factors related to socioeconomic status that are associated with diet quality and could potentially confound our results.

In summary, the HEI-2005 was inversely associated with risk of major chronic disease, including CHD, stroke, diabetes, and total cancer. Thus, greater adherence to the 2005 Guidelines may reduce risk of major chronic disease. The AHEI-2010, which explicitly emphasizes high intakes of whole grains, PUFA, nuts, and fish and reductions in red and processed meats, refined grains, and sugar-sweetened beverages, was also associated with lower risk of chronic diseases; in models that adjusted for both scores, the AHEI-2010 was more strongly associated with CHD and diabetes. These results suggest that future revisions of Dietary Guidelines may consider special emphasis on selecting the healthiest choices within each food group, specifically high-quality grains (whole vs. refined grains) and protein sources (nuts/beans/fish vs. red/processed meats), and encouraging greater intake of PUFA and reducing intake of sugar-sweetened beverages. Adherence to dietary guidelines that include such modifications could potentially reduce risk of chronic disease even further, especially CHD and diabetes.

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