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Original Contribution

Index-based Dietary Patterns and Risk of Colorectal Cancer

The NIH-AARP Diet and Health Study

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The authors compared how four indexes—the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score—are associated with colorectal cancer in the National Institutes of Health-AARP Diet and Health Study ($n = 492,382$). To calculate each score, they merged data from a 124-item food frequency questionnaire completed at study entry (1995–1996) with the MyPyramid Equivalents Database (version 1.0). Other variables included energy, nutrients, multivitamins, and alcohol. Models were stratified by sex and adjusted for age, ethnicity, education, body mass index, smoking, physical activity, and menopausal hormone therapy (in women). During 5 years of follow-up, 3,110 incident colorectal cancer cases were ascertained. Although the indexes differ in design, a similarly decreased risk of colorectal cancer was observed across all indexes for men when comparing the highest scores with the lowest: Healthy Eating Index-2005 (relative risk (RR) = 0.72, 95% confidence interval (CI): 0.62, 0.83); Alternate Healthy Eating Index (RR = 0.70, 95% CI: 0.61, 0.81); Mediterranean Diet Score (RR = 0.72, 95% CI: 0.63, 0.83); and Recommended Food Score (RR = 0.75, 95% CI: 0.65, 0.87). For women, a significantly decreased risk was found with the Healthy Eating Index-2005, although Alternate Healthy Eating Index results were similar. Index-based dietary patterns that are consistent with given dietary guidelines are associated with reduced risk.

colorectal neoplasms; food habits; risk

Abbreviations: CI, confidence interval; NIH, National Institutes of Health; RR, relative risk.

The development of different diet quality indexes has increased in the last decade, as has interest in understanding how indexes predict health outcomes. Index-based dietary patterns are an appealing method to address the complexity of diet and the likely interaction among multiple dietary components. Use of an index-based method—calculating a numerical score based on a priori knowledge—is one way to comprehensively approach the study of the relation between diet and cancer (1, 2).

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Assessing overall dietary patterns is an important alternative to traditional methods in nutritional epidemiology that have focused only on single nutrients (3). Although it is important to understand the role of individual dietary constituents, there are inherent statistical limitations with the single-nutrient approach because intakes are often intercorrelated (4). Diet quality indexes preserve some of the multidimensional aspects of food and allow for the analysis of nonnutrient components without reducing dietary intake to a single nutrient or a series of nutrients (3).

In this analysis, we examine four indexes—the Healthy Eating Index-2005 (5), Alternate Healthy Eating Index (6–8), Mediterranean Diet Score (9, 10), and Recommended Food Score (11)—in relation to colorectal cancer in the National Institutes of Health (NIH)-AARP Diet and Health Study cohort. These indexes share some similarities, but they differ in philosophy and design. The Healthy Eating Index-2005 replaces the original Healthy Eating Index (12), aligns with *Dietary Guidelines for Americans, 2005* (13), and uses an energy-adjusted density approach. The Alternate Healthy Eating Index is grounded in a different food guide, the Healthy Eating Pyramid (14). The Mediterranean Diet Score was designed to reflect key components of the Mediterranean diet and is dependent on the distribution of intake within a given population to determine cutpoints for scoring; the components are also energy adjusted. The Recommended Food Score is the simplest approach and counts whether foods were consumed at least weekly from a specified food list defined by dietary guidelines.

MATERIALS AND METHODS

Study participants

We used data from the NIH-AARP Diet and Health Study, a prospective cohort study designed to investigate diet and cancer. AARP members who were aged between 50 and 71 years and residents of six states (California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania) or two metropolitan areas (Atlanta, Georgia, and Detroit, Michigan) were contacted in 1995–1996 to participate in the NIH-AARP Diet and Health Study. Eighteen percent (n = 617,119) returned the questionnaire. Of the 567,169 complete surveys (15), we excluded those from people who had died or had moved from the study area (n = 582), duplicates (n = 179), and the survey from the one participant who withdrew. After reviewing these surveys (n = 566,407), we further excluded questionnaires completed by proxy (n = 15,760), by respondents with previous cancer (n = 52,867) or end-stage renal disease (n = 997), and by individuals with calorie outliers using a Box-Cox transformation (n = 4,401) (16). The cohort we used in these analyses included 492,382 people (293,615 men and 198,767 women).

Cohort follow-up and identification of cancer cases

Study participants were followed from enrollment in 1995–1996 through December 31, 2000. Vital status was determined by annual linkage of the cohort to the Death Master File from the Social Security Administration, follow-up searches of the National Death Index for subjects that match to the Death Master File, cancer registry linkage, questionnaire responses, and responses to other mailings. Incident cases of cancer were identified by probabilistic linkage between the NIH-AARP Diet and Health Study membership and eight state cancer registry databases. In a previous analysis to study the validity of this approach, approximately 90 percent of all cancers were assessed (15). Further details on the design of this cohort have been described elsewhere (15). The NIH-AARP Diet and Health Study was approved by the Special Studies Institutional Review Board of the National Cancer Institute.

During follow-up, we identified 3,110 incident colorectal cancer cases (2,151 in men and 959 in women). Cases were invasive and defined by *International Classification of Diseases*, Tenth Revision, codes C180–C189, C199, C209, and C260. If multiple cancers were diagnosed in the same participant, we included the colorectal cancer case only if it was the first malignancy diagnosed during the follow-up period. Cases diagnosed with colon and rectal cancer on the same day were considered to be cases for both sites. We further classified colorectal cancer by tumor site: proximal colon, distal colon, and rectum.

Exposure assessment

Study participants completed a 124-item food frequency questionnaire, an early version of the Diet History Questionnaire, to assess dietary intake over the past year. The Diet History Questionnaire has been calibrated (15, 17), and further validation was done with the AARP food frequency questionnaire by use of two 24-hour recalls within the NIH-AARP Diet and Health Study (18).

To construct the scores for all four indexes, we used food group and nutrient variables from the AARP food frequency questionnaire. We merged the MyPyramid Equivalents Database, version 1.0, with the AARP food frequency questionnaire data to calculate pyramid equivalents for grains (including whole grains), vegetables (including dark-green vegetables, orange vegetables, legumes, starchy vegetables, and other vegetables), fruit, dairy, meat and beans (including poultry, fish, nuts, soy, and legumes), oils, solid fat, added sugars, and alcohol. We also created variables for white meat, red meat, multivitamins, whole fruit, vegetables (excluding white potatoes), processed meat, and calories from alcohol (based on drinks of beer, wine, and liquor). Additionally, we generated nutrient estimates for saturated fat, polyunsaturated fat, monounsaturated fat, *trans* fat, cereal fiber, sodium, and alcohol. Using the pyramid equivalents and other variables, we calculated component and index scores for the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score on the basis of published descriptions of the indexes and previous work with food frequency questionnaire data (19). Table 1 identifies the components and standards for optimal scoring; specific details are described below.

Healthy Eating Index-2005

The Healthy Eating Index-2005 scores 12 components for a total of 100 points (5). Six components—total grains;

TABLE 1. Components and optimal quantities for scoring standards for each component of the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score

	Healthy Eating Index-2005 (total = 100 points)	Alternate Healthy Eating Index (total = 87.5 points)	Mediterranean Diet Score (total = 9 points)	Recommended Food Score (total = 45 points)
Grains				
Total grains	≥3 ounces*/1,000 kcal			
Whole grains	≥1.5 ounces/1,000 kcal		Whole grains ≥ median: 1.19 and 0.98 ounces‡	5 items†
Vegetables				
Total vegetables	≥1.1 cups*/1,000 kcal	≥2.5 cups/day	Excluding potatoes ≥ median: 1.85 and 1.87 cups‡	18 items§
Dark-green and orange vegetables, legumes	≥0.4 cups/1,000 kcal			
Fruit				
Total fruit	≥0.8 cups/1,000 kcal	≥2 cups/day	Fruit ≥ median: 2.29 and 2.32 cups‡	15 items¶
Whole fruits	≥0.4 cups/1,000 kcal			
Milk	≥1.3 cups/1,000 kcal			2 items#
Meats, fish, legumes, and nuts	≥2.5 ounces/1,000 kcal			5 items**
		White meat:red meat ratio = 4	Red and processed meat < median: 3.00 and 1.80 ounces‡	
			Fish ≥ median: 0.66 and 0.53 ounces‡	
			Legumes ≥ median: 0.09 and 0.06 cups‡	
		Nuts and soy: 1 ounce/day	Nuts ≥ median: 0.36 and 0.23 ounces‡	
Oils	≥12 g/1,000 kcal	Polyunsaturated:saturated fat ratio = ≥1	Monounsaturated:saturated fat ratio < median: 1.24 and 1.22‡	
Fat	Saturated fat: ≤7% kcal	*Trans* fat: ≤0.5% kcal		
Sodium	≤700 mg/1,000 kcal			
Fiber		Cereal fiber: 15 g/day		
Calories from solid fat, alcohol, and added sugar	≤20% kcal			
Alcohol		Men: 1.5–2.5 drinks/day	5–25 g/day	
		Women: 0.5–1.5 drinks/day		
Multivitamins		Regular use††		

* One ounce = 28.35 g; 1 cup = 0.24 liter.

† Includes dark bread, cornbread, tortillas, high-fiber cereals, cooked cereals, and grits.

‡ Median intake values for men and women, respectively. Mediterranean Diet Score components are adjusted for total energy intake (density method) and standardized to 2,000 calories in women and 2,500 calories in men.

§ Includes beans, tomatoes, broccoli, spinach, carrots, lettuce, sweet potatoes, white potatoes, corn, peas, green pepper, tomato juice, tomato sauce, coleslaw, cauliflower, tomato salsa, mixed vegetables, cauliflower, Brussels sprouts, and greens.

¶ Includes apples and pears, oranges, cantaloupe, orange or grapefruit juice, grapefruit, other fruit juices, bananas, strawberries, applesauce, grapes, dried fruit, melon, and peaches, nectarines, and plums.

Includes 2% or 1% (fat) milk and skim milk.

** Includes chicken white meat (without skin), chicken dark meat (without skin), turkey, fish and other seafood with no fat added, and water-packed tuna.

†† Regular use defined as at least every other day.

whole grains; total vegetables; dark-green vegetables, orange vegetables, and legumes; total fruit; and whole fruit—are worth 0–5 points; five components—milk; meats and beans; oils; saturated fat; and sodium—are worth 0–10 points; and one component—calories from solid fat, alcohol, and added sugar—is worth 0–20 points. Scores are evenly prorated except for saturated fat and sodium; these components are prorated from 0 to 8 and from 8 to 10 points (with 8 and 10 points representing acceptable and optimal levels, respectively). Components and standards for scoring are energy adjusted on a density basis (per 1,000 calories). We adapted the scoring for alcohol in the calories from the solid fat, alcohol, and added sugar component by estimating calories from drinks of alcoholic beverages rather than grams of alcohol and carbohydrate.

Alternate Healthy Eating Index

The Alternate Healthy Eating Index scores nine components for a total of 87.5 points (6–8). Eight components—vegetables, fruit, nuts and soy, white:red meat ratio, *trans* fat, polyunsaturated:saturated fat ratio, cereal fiber, and alcohol—are worth 0–10 points, and scores are evenly prorated on the basis of standards established previously. The multivitamin component is scored as either 7.5 points for regular intake of multivitamins or 2.5 points for intake less than every other day. Because the AARP food frequency questionnaire did not collect information on length of time of multivitamin use, we modified this component from the original Alternate Healthy Eating Index to reflect regular intake, rather than years of intake.

Mediterranean Diet Score

The Mediterranean Diet Score assesses nine components for a total of 9 points (9, 10, 20). One point is scored for intake *at or greater than* the sex-specific median for whole grains, vegetables, fruit, fish, legumes, and nuts; and 1 point is given for intake *less than* the sex-specific median for red and processed meat and the monounsaturated:saturated fat ratio. Alcohol intake is scored by predetermined cutpoints. Components are energy adjusted by multiplying by 2,500 calories for men (2,000 calories for women) and dividing by reported energy intake (9, 10).

Recommended Food Score

The Recommended Food Score assesses 45 components for a total of 45 points (11). One point each is given for at least weekly intake of food items identified from the AARP food frequency questionnaire that are consistent with dietary guidance: five whole-grain bread/cereal items, 18 vegetable items, 15 fruit items, two low-fat milk items, and five lean-meat items. Our Recommended Food Score had 45 items versus Kant's 23-item Recommended Food Score, because the AARP food frequency questionnaire had 124 items compared with her 62-item food frequency questionnaire. Researchers have also modified the Recommended Food Score on the basis of other food frequency questionnaires of varying length (6), and we conferred with Kant to review our food list (A. K. Kant, City University of New York, Flushing, New York, personal communication, 2005).

Statistical analysis

We used SAS, version 8.1, software (SAS Institute, Inc., Cary, North Carolina) to generate descriptive statistics for specific dietary factors, demographics, and lifestyle characteristics. We calculated Pearson's correlations to compare the total scores of the four indexes. We used Cox proportional hazard models (21) with person-years as the underlying time metric to model the relative risk of colorectal cancer separately for each of the four indexes. We ran additional models to investigate site-specific associations for proximal colon, distal colon, and rectum. Finally, to investigate the independent effects of each individual component, we ran four different index-specific models to assess the risk associated with each component within the four indexes, adjusting for the other components in the given index and specified covariates.

We adjusted for the following covariates and potential risk factors for colorectal cancer: age (<55, 55–59, 60–64, 65–69, ≥70 years), ethnicity (White, Black, other), education (less than high school, high school, some college, college graduate), body mass index (18.5–24.9, 25–29, 30–34, 35–39, ≥40 kg/m^2), smoking (never smoker, former smoker of ≤1 pack per day, former smoker of >1 pack per day, current smoker of ≤1 pack per day, current smoker of >1 pack per day), physical activity (≥20 daily minutes reported rarely or never, 1–3 times per month, 1–2 times per week, 3–4 times per week, ≥5 times per week), energy intake (calories), and menopausal hormone therapy (for women). Missing values were included in the model as dummy variables. Energy intake was included in the final models for all indexes to reduce measurement error and to allow for comparability across the indexes. We ran models with and without energy, and the estimates did not differ appreciably.

RESULTS

Table 2 provides descriptive characteristics across the quintile scores of the indexes. Compared with study participants in the lowest quintiles (quintile 1), those in the highest quintiles (quintile 5) with the highest scores for the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score were more likely to be older, college graduates, physically active, and nonsmokers and to have a lower body mass index. Predictably, the higher the Alternate Healthy Eating Index and Recommended Food Score assessments were, the higher the reported calories. The converse was true for the Healthy Eating Index-2005 and Mediterranean Diet Score assessments, because these two indexes use methods to adjust for calories.

Table 3 includes the correlations between the total scores for the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score. The scores are all somewhat correlated; the coefficients range from 0.43 to 0.63 for men and from 0.39 to 0.56 for women. Total scores for the Healthy Eating Index-2005 ($r = 0.63$ and $r = 0.56$) and Alternate Healthy Eating Index ($r = 0.54$ and $r = 0.55$) were most strongly correlated with the Mediterranean Diet Score in both men

TABLE 2. Descriptive characteristics of NIH-AARP* Diet and Health Study participants based on upper (quintile 5) and lower (quintile 1) index scores for the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score

	No.	Range of index (points)	Colorectal cancer (cases)	Age (years)	Ethnicity (% white)	Education (% college graduates)	Body mass index (kg/m^2)	Smoking (% never)	Physical activity (% ≥5 times/week)	Energy intake (calories)
						Men				
Healthy Eating Index-2005										
Quintile 1	58,723	21–55	520	61.5	93.0	33.5	27.3	20.3	15.6	2,350
Quintile 5	58,723	76–97	360†	62.8†	92.3†	52.6†	26.9†	36.7†	28.2†	1,786†
Alternate Healthy Eating Index										
Quintile 1	58,723	15–41	509	61.9	93.0	33.5	27.6	26.8	13.2	1,580
Quintile 5	58,723	56–88	370†	62.3†	94.1†	54.8†	26.7†	33.4†	31.1†	2,451†
Mediterranean Diet Score										
Quintile 1	50,217	0–2	431	61.5	93.6	33.4	27.7	23.9	15.5	2,258
Quintile 5	75,210	6–9	443†	62.6	92.6†	54.3†	26.7†	29.3†	27.5†	1,865
Recommended Food Score										
Quintile 1	62,472	0–6	529	61.6	90.7	34.3	27.6	23.4	14.2	1,660
Quintile 5	60,008	16–38	404‡	62.6†	91.9†	51.5†	27.0†	36.2†	29.3†	2,411†
						Women				
Healthy Eating Index-2005										
Quintile 1	39,753	20–60	218	61.2	89.5	21.8	27.1	36.1	10.5	1,756
Quintile 5	39,753	79–94	167†	62.5†	89.7†	35.8†	26.5†	49.8†	21.2†	1,484†
Alternate Healthy Eating Index										
Quintile 1	39,753	13–41	220	61.9	89.4	20.4	27.0	42.2	9.4	1,563
Quintile 5	39,753	56–88	173	62.0†	88.8†	39.2†	25.9†	46.0†	24.1†	1,966†
Mediterranean Diet Score										
Quintile 1	32,197	0–2	168	61.4	91.1	21.2	27.6	40.5	10.6	1,706
Quintile 5	44,438	6–9	197§	62.1†	89.1†	39.2†	25.9†	46.1†	22.3†	1,510†
Recommended Food Score										
Quintile 1	38,024	0–6	176	61.3	88.0	22.2	27.1	37.2	10.0	1,214
Quintile 5	38,539	17–38	181	62.2†	86.8†	33.8†	26.7†	51.7†	22.5†	2,063†

* NIH-AARP, National Institutes of Health-AARP.
† Difference between quintile 1 and quintile 5 (t test or chi-square statistic) is statistically significant at $p < 0.0001$.
‡ Difference between quintile 1 and quintile 5 (t test or chi-square statistic) is statistically significant at $p = 0.0005$.
§ Difference between quintile 1 and quintile 5 (t test or chi-square statistic) is statistically significant at $p = 0.0092$.

and women, respectively. The Recommended Food Score was most strongly correlated with the Alternate Healthy Eating Index for men ($r = 0.53$) and women ($r = 0.51$).

Table 4 presents the relative risks for colorectal cancer according to quintiles of index score among men and women. All four indexes were associated with a reduced risk of colorectal cancer in men (quintile 5 vs. quintile 1), adjusting for age, ethnicity, education, body mass index, smoking, physical activity, energy, and menopausal hormone therapy (women only). The relative risks and confidence intervals were very similar in the multivariate models: Healthy Eating Index-2005 (relative risk (RR) = 0.72, 95 percent confidence interval (CI): 0.62, 0.83); Alternate Healthy Eating Index (RR = 0.70, 95 percent CI: 0.61, 0.81); Mediterranean Diet Score (RR = 0.72, 95 percent CI: 0.63, 0.83); and Recommended Food Score (RR = 0.75, 95 percent CI: 0.65, 0.87). A reduction in risk was also found for women in the Healthy Eating Index-2005 (RR = 0.80, 95 percent CI: 0.64, 0.98). A similar relation was seen for women with the Alternate Healthy Eating Index, but this was not statistically significant in the adjusted model using this index (RR = 0.83, 95 percent CI: 0.66, 1.05).

Table 5 compares site-specific risks for proximal colon (769 cases in men and 438 cases in women), distal colon (707 cases in men and 253 cases in women), and rectum (631 cases in men and 259 cases in women). Among men, the Healthy Eating Index-2005, Alternate Healthy Eating Index, and Mediterranean Diet Score had a statistically significant reduction in risk for distal colon cancer, while the Recommended Food Score had a reduction in risk for both proximal colon and distal colon. Rectal cancer risk was reduced among men when measuring diet with the Healthy Eating Index-2005 (RR = 0.56, 95 percent CI: 0.43, 0.74),

TABLE 3. Pearson's correlation coefficients for men ($n = 293{,}540$) and women ($n = 199{,}381$) among total summary scores for the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score

	Healthy Eating Index-2005*		Alternate Healthy Eating Index*		Mediterranean Diet Score*		Recommended Food Score*	
	Men	Women	Men	Women	Men	Women	Men	Women
Healthy Eating Index-2005			0.43	0.43	0.63	0.56	0.48	0.46
Alternate Healthy Eating Index					0.54	0.56	0.53	0.51
Mediterranean Diet Score							0.44	0.39
Recommended Food Score								

* All $p < 0.0001$.

Alternate Healthy Eating Index (RR = 0.56, 95 percent CI: 0.42, 0.74), and Mediterranean Diet Score (RR = 0.69, 95 percent CI: 0.54, 0.88) but not with the Recommended Food Score (RR = 0.86, 95 percent CI: 0.66, 1.11). Women in the highest quintile of the Healthy Eating Index-2005 were found to have a reduced risk for distal colon cancer (RR = 0.64, 95 percent CI: 0.41, 0.98). None of the other associations was statistically significant among women.

TABLE 4. Relative risks and 95% confidence intervals for colorectal cancer according to quintiles of diet quality indexes for the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score

	Age-adjusted model*				Multivariate model†			
	Men (n = 293,615)		Women (n = 198,767)		Men (n = 293,615)		Women (n = 198,767)	
	Relative risk	95% confidence interval	Relative risk	95% confidence interval	Relative risk	95% confidence interval	Relative risk	95% confidence interval
Healthy Eating Index-2005								
Quintile 1	1.00		1.00		1.00		1.00	
Quintile 2	0.81	0.71, 0.92	0.89	0.74, 1.08	0.84	0.74, 0.96	0.95	0.79, 1.16
Quintile 3	0.79	0.70, 0.90	0.83	0.68, 1.01	0.85	0.75, 0.97	0.92	0.75, 1.12
Quintile 4	0.72	0.63, 0.82	0.77	0.63, 0.94	0.80	0.70, 0.92	0.87	0.71, 1.07
Quintile 5	0.63	0.55, 0.72	0.69	0.56, 0.84	0.72	0.62, 0.83	0.80	0.64, 0.98
Alternate Healthy Eating Index								
Quintile 1	1.00		1.00		1.00		1.00	
Quintile 2	0.90	0.79, 1.02	0.89	0.73, 1.08	0.90	0.79, 1.02	0.91	0.75, 1.11
Quintile 3	0.85	0.74, 0.99	0.85	0.69, 1.03	0.84	0.73, 0.96	0.87	0.71, 1.07
Quintile 4	0.81	0.71, 0.93	0.89	0.763, 1.08	0.81	0.70, 0.92	0.91	0.71, 1.13
Quintile 5	0.71	0.62, 0.82	0.81	0.66, 0.98	0.71	0.61, 0.82	0.83	0.66, 1.05
Mediterranean Diet Score								
Quintile 1	1.00		1.00		1.00		1.00	
Quintile 2	0.94	0.83, 1.08	1.02	0.83, 1.25	0.98	0.85, 1.12	1.06	0.86, 1.30
Quintile 3	0.80	0.70, 0.91	0.94	0.77, 1.15	0.85	0.74, 0.97	1.00	0.82, 1.22
Quintile 4	0.81	0.70, 0.92	0.73	0.59, 0.90	0.88	0.77, 1.01	0.79	0.64, 0.99
Quintile 5	0.63	0.55, 0.72	0.79	0.64, 0.97	0.72	0.63, 0.83	0.89	0.72, 1.11
Recommended Food Score								
Quintile 1	1.00		1.00		1.00		1.00	
Quintile 2	0.82	0.72, 0.93	1.02	0.83, 1.25	0.83	0.73, 0.94	1.07	0.87, 1.32
Quintile 3	0.78	0.69, 0.89	1.02	0.84, 1.25	0.80	0.70, 0.91	1.10	0.90, 1.36
Quintile 4	0.79	0.69, 0.91	0.99	0.81, 1.21	0.81	0.71, 0.93	1.08	0.87, 1.34
Quintile 5	0.73	0.64, 0.83	0.93	0.76, 1.14	0.75	0.65, 0.87	1.01	0.80, 1.28

* Adjusted for age.

† Adjusted for age, ethnicity, education, body mass index, smoking, physical activity, and energy (and menopausal hormone therapy, women only).

TABLE 5. Relative risks and 95% confidence intervals for proximal colon, distal colon, and rectal cancer sites comparing highest with lowest quintiles of diet quality indexes (quintile 5 vs. quintile 1) for the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score

	Multivariate model*			
	Men (*n* = 293,615)		Women (*n* = 198,767)	
	Relative risk	95% confidence interval	Relative risk	95% confidence interval
Healthy Eating Index-2005				
Proximal	0.94	0.74, 1.19	0.83	0.61, 1.14
Distal	0.67	0.52, 0.86	0.64	0.41, 0.98
Rectal	0.56	0.43, 0.74	0.89	0.60, 1.32
Alternate Healthy Eating Index				
Proximal	0.82	0.64, 1.06	0.75	0.54, 1.05
Distal	0.75	0.75, 0.96	0.93	0.59, 1.46
Rectal	0.56	0.42, 0.74	0.95	0.61, 1.48
Mediterranean Diet Score				
Proximal	0.83	0.66, 1.04	0.84	0.61, 1.14
Distal	0.68	0.53, 0.86	1.18	0.76, 1.84
Rectal	0.69	0.54, 0.88	0.75	0.50, 1.21
Recommended Food Score				
Proximal	0.68	0.53, 0.86	1.09	0.77, 1.53
Distal	0.76	0.59, 0.97	0.90	0.56, 1.42
Rectal	0.86	0.66, 1.11	1.03	0.64, 1.66

* Adjusted for age, ethnicity, education, body mass index, smoking, physical activity, and energy (and menopausal hormone therapy, women only).

Tables 6 and 7 include the risks for four models (one for each index) for the index-specific components for men and women, adjusting for the other components within each index. Among men, a ‘‘grains/fiber’’ construct is present in all indexes and, although it is operationalized differently as whole grain density (Healthy Eating Index-2005), cereal fiber (Alternate Healthy Eating Index), whole-grain intake (Mediterranean Diet Score), or dark breads (Recommended Food Score), each of these components is associated with a significant reduction in risk among men. Also among men, ‘‘vegetables’’ are a favorable construct in the Alternate Healthy Eating Index (as total vegetables without white potatoes) and the Recommended Food Score (dark-green salad). Similarly, among women, ‘‘dairy’’ is a beneficial construct in the Healthy Eating Index-2005 as milk density (RR = 0.96, 95 percent CI: 0.94, 0.98) and the Recommended Food Score as fat-free milk (RR = 0.77, 95 percent CI: 0.66, 0.88) and reduced-fat milk (RR = 0.86, 95 percent CI: 0.75, 0.98) but is not part of either the Alternate Healthy Eating Index or Mediterranean Diet Score.

DISCUSSION

We found a decreased risk of colorectal cancer that was comparable across all indexes—Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score—for men when comparing the highest scores (quintile 5) with the lowest (quintile 1). However, for women, a significantly decreased risk was found only with the Healthy Eating Index-2005, although the point estimates and range in the confidence intervals for the Alternate Healthy Eating Index were very similar to those of the Healthy Eating Index-2005. It seems that these indexes have some of the same individuals in the top quintile, but because of variation in the definitions of optimal diet quality and the scoring mechanisms, the indexes are not capturing all of the same study participants in that quintile.

Other researchers have previously linked specific diet quality indexes with different health outcomes. The Alternate Healthy Eating Index has been associated with a decreased risk of chronic disease, especially cardiovascular disease (6–8). Other indexes, such as the Mediterranean Diet Score and Recommended Food Score, have consistently been found to be associated with reduced mortality (9–11, 22–25). Fewer studies have investigated how these scores may predict cancer incidence (26, 27). Fung et al. (26) found that women with higher Recommended Food Score assessments had a lower risk of estrogen receptor-negative breast cancer (the Alternate Healthy Eating Index and Mediterranean Diet Score were not significant). However, Mai et al. (27) found that the 23-item Recommended Food Score was associated with a reduced risk of lung cancer but not breast cancer. Additionally, they found no relation between the Recommended Food Score and colorectal and other cancers in women. These null results for colorectal cancer are consistent with our findings with the Recommended Food Score for women.

Earlier work also compared *multiple* index-based scores with specific markers of disease. Kant and Graubard (28) found that the Recommended Food Score and Dietary Diversity Score performed as well as the original Healthy Eating Index when investigating correlations with biomarkers related to obesity, dietary intake, cardiovascular disease, and diabetes mellitus. However, Fung et al. (20) had better results with the Alternate Healthy Eating Index and Mediterranean Diet Score, compared with the Recommended Food Score, original Healthy Eating Index, and Diet Quality Index-Revised. High scores from the Alternate Healthy Eating Index and Mediterranean Diet Score were associated with lower plasma concentrations of markers of inflammation and endothelial dysfunction, and high scores from the Recommended Food Score were associated with only one of the biomarkers; the original Healthy Eating Index and the Diet Quality Index-Revised were not associated with any of the biomarkers.

We compared four diet quality indexes separately for men and women. Notably, the Healthy Eating Index-2005 became available in 2007, and its predictive validity has not been tested previously. When we investigated each score with colorectal cancer among men, we did not find evidence that any one of the tools performed better than the other.

TABLE 6. Index-specific relative risks and 95% confidence intervals for colorectal cancer for each component of the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score among men (*n* = 293,615)

	Healthy Eating Index-2005*		Alternate Healthy Eating Index*		Mediterranean Diet Score*		Recommended Food Score*	
	Relative risk	95% confidence interval	Relative risk	95% confidence interval	Relative risk	95% confidence interval	Relative risk	95% confidence interval
Grains								
Total grains	0.96	0.91, 1.02					0.89	0.81, 0.97†
Whole grains	0.94	0.90, 0.98			0.85	0.78, 0.93		
Vegetables								
Total vegetables	0.99	0.94, 1.05	0.98	0.95, 0.99‡	0.94	0.86, 1.03‡	0.82	0.74, 0.91§
Dark-green and orange vegetables, legumes	0.98	0.94, 1.02						
Fruit								
Total fruit	1.00	0.96, 1.05	1.00	0.98, 1.01	0.94	0.86, 1.03		
Whole fruits	0.96	0.92, 1.00						
Milk	0.98	0.97, 1.00						
Meats, fish, legumes, and nuts	1.02	0.99, 1.05						
Nuts and soy			0.99	0.98, 1.01				
White:red meat ratio			0.99	0.97, 1.01				
Red and processed meat					0.94	0.86, 1.03¶		
Fish					0.97	0.89, 1.06		
Legumes					0.96	0.88, 1.05		
Nuts					0.93	0.85, 1.01		
Oils	0.98	0.96, 1.00						
Saturated fat	1.01	0.99, 1.02						
Fatty acid ratio			1.00	0.68, 1.47#	1.01	0.92, 1.10**		
Trans fat			0.99	0.97, 1.02				
Sodium	1.01	0.98, 1.04						
Fiber			0.97	0.94, 0.99				
Calories from solid fat, alcohol, and added sugar	1.00	0.99, 1.01						
Alcohol			0.99	0.98, 1.00	0.91	0.82, 1.00		
Multivitamins			0.99	0.97, 1.01				

* Each model (for the Healthy Eating Index-2005, for the Alternate Healthy Eating Index, for the Mediterranean Diet Score, and for the Recommended Food Score) is adjusted for age, ethnicity, education, body mass index, smoking, physical activity, and all other components within the specific index.
† Dark bread item only.
‡ Excluding white potatoes.
§ Green salad item only.
¶ Note that the red meat/processed meat component is reverse scored.
# Polyunsaturated:saturated fat.
** Monounsaturated:saturated fat.

Among women, the Healthy Eating Index-2005 was the only index that was associated with a statistically significant reduced risk for colorectal cancer and, specifically, for distal colon cancer.

We considered the influence of each component within the indexes as well as the summary score. The component analysis is not completely consistent with our conceptual goals related to analyzing dietary patterns because, without interaction terms, these models assume that the components act independently, rather than synergistically. We found independent reduced risk for constructs measuring whole grains/fiber, vegetables, and reduced-fat milk. Among men, we found some evidence of reduced risk whether grains were assessed as whole grains (Healthy Eating Index-2005 and Mediterranean Diet Score), fiber (Alternate Healthy Eating Index), or a single dark bread item

TABLE 7. Index-specific relative risks and 95% confidence intervals for colorectal cancer for each component of the Healthy Eating Index-2005, Alternate Healthy Eating Index, Mediterranean Diet Score, and Recommended Food Score among women ($n = 198,767$)

	Healthy Eating Index-2005*		Alternate Healthy Eating Index*		Mediterranean Diet Score*		Recommended Food Score*	
	Relative risk	95% confidence interval	Relative risk	95% confidence interval	Relative risk	95% confidence interval	Relative risk	95% confidence interval
Grains								
Total grains	0.98	0.90, 1.07						
Whole grains	0.96	0.90, 1.02			0.95	0.83, 1.08		
Vegetables								
Total vegetables	1.04	0.95, 1.13	1.01	0.98, 1.04†	0.98	0.85, 1.12†	1.18	1.01, 1.38‡
Dark-green and orange vegetables, legumes	0.96	0.91, 1.01						
Fruit								
Total fruit	0.99	0.91, 1.07	0.99	0.97, 1.02	1.04	0.90, 1.19		
Whole fruits	1.03	0.95, 1.12						
Milk	0.96	0.94, 0.98					0.86	0.75, 0.98§
							0.77	0.66, 0.88¶
Meats, fish, legumes, and nuts	1.00	0.96, 1.04						
Nuts and soy			0.99	0.96, 1.01				
White:red meat ratio			0.99	0.97, 1.02				
Red and processed meat					0.84	0.74, 0.96#		
Fish					1.00	0.88, 1.14		
Legumes					0.94	0.83, 1.08		
Nuts					0.93	0.85, 1.02		
Oils	1.00	0.98, 1.03						
Saturated fat	1.00	0.98, 1.03						
Fatty acid ratio			1.08	0.75, 1.57**	1.01	0.89, 1.15††		
Trans fat			1.01	0.98, 1.05				
Sodium	0.97	0.93, 1.01						
Fiber			0.98	0.94, 1.02				
Calories from solid fat, alcohol, and added sugar	1.00	0.98, 1.01						
Alcohol			1.00	0.98, 1.02	0.93	0.78, 1.02		
Multivitamins			0.97	0.95, 1.00				

* Each model (for the Healthy Eating Index-2005, for the Alternate Healthy Eating Index, for the Mediterranean Diet Score, and for the Recommended Food Score) is adjusted for age, ethnicity, education, body mass index, smoking, physical activity, menopausal hormone therapy, and all other components within the specific index.
† Excluding white potatoes.
‡ Corn item only.
§ Reduced-fat milk (1% and 2% milk).
¶ Fat-free milk.
\# Note that the red meat/processed meat component is reverse scored.
** Polyunsaturated:saturated fat.
†† Monounsaturated:saturated fat.

(Recommended Food Score) and, similarly, whether vegetables were assessed as pyramid equivalents (Alternate Healthy Eating Index), an amount greater than average in the cohort (Mediterranean Diet Score), or a single salad item (Recommended Food Score). Among women, it may be that the proposed protective effects of calcium, vitamin D, and/or dairy (29) partially explain why the Healthy Eating Index-2005—with its dairy component—was the only predictive index.

A summary score is most instructive when scores are very high or low. Here, we were able to accurately separate those individuals with favorable diets (quintile 5) compared with those with less-favorable diets (quintile 1). In these quintiles, we can most appropriately capture those who are scoring well on virtually all of the components compared with those who are not. However, the indexes are not as easy to interpret in the middle quintiles, because these scores include some individuals with the same score but very different diets.

We found strong relations with all scores for a reduced risk of colorectal cancer for men but not with all scores for women. This may be due to inherent differences between how men and women complete the AARP food frequency questionnaire, leading to increased measurement error and nondifferential bias among women (30, 31), the range of intake reported by women, the smaller sample size and fewer cases in women, or perhaps differences in the etiology of colorectal cancers between men and women. It is also possible that the reduced risk found for some, or all, of the scores is due to confounding by other measured or unmeasured lifestyle attributes that are related to dietary choices and colorectal cancer development. It was important to conduct analyses separately for men and women, because of meaningful differences in dietary intake and other covariates and because the standards used in developing the Mediterranean Diet Score vary by sex; for example, the median intake of red and processed meat was 3.0 and 1.8 ounces for men and women, respectively. (One ounce = 28.35 g.)

The index scores do not necessarily provide new knowledge related to specific dietary constituents and colorectal cancer. However, they do provide critical context for public health messages and dietary guidance. These findings suggest that, to reduce the risk of colorectal cancer, men can comply with the 2005 Dietary Guidelines (Healthy Eating Index-2005), adhere to the Healthy Eating Pyramid (Alternate Healthy Eating Index), follow an average Mediterranean diet (Mediterranean Diet Score), or increase the number of healthy recommended foods (Recommended Food Score). There are common themes across these eating patterns, and this is likely why we see a similar benefit from the indexes.

For women, this message is not quite as straightforward. We observed a reduced risk for women only when they eat according to the 2005 Dietary Guidelines, as defined by the Healthy Eating Index-2005. However, it could be said that the Recommended Food Score also operationalizes these recommendations. Although the Recommended Food Score is appealing because of its simplicity, the complexity of the Healthy Eating Index-2005 does appear to add some predictive capability. This may be due to the inclusion of a dairy component with a high standard of intake, the energy adjustment process, the combination and synergism among the components selected in the construction of the index, the penalty for calories from solid fat, alcohol, and added sugar, or some other unidentified reasons.

None of the indexes was created to be used specifically for colorectal cancer. However, previous analyses have found that, despite some key differences in food guidance philosophies, recommendations are relatively consistent for healthy persons and for specific disease states (32). If our goal was to improve the predictive capability for any of the tools with colorectal cancer as a given outcome, a next step would be to apply weights based on our component analysis (which suggest, for example, that the whole grains/fiber and dairy constructs may be somewhat more critical) and run these models in a different population to assess validity.

Diet has long been considered a causal factor in the genesis of colorectal cancer. However, we need not wait until the specific mechanisms underlying these relations are fully determined to influence dietary intake and the food environment. Index-based methods illustrate that dietary patterns consistent with given dietary guidelines are associated with a reduced risk in men and in women when measured with the Healthy Eating Index-2005. This work is particularly important as dietary guidance and messages about cancer-preventive dietary patterns continue to be refined.

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