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High Diet Quality Is Associated with a Lower Risk of Cardiovascular Disease and All-Cause Mortality in Older Men[1–3]

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Abstract

Although diet quality is implicated in cardiovascular disease (CVD) risk, few studies have investigated the relation between diet quality and the risks of CVD and mortality in older adults. This study examined the prospective associations between dietary scores and risk of CVD and all-cause mortality in older British men. A total of 3328 men (aged 60–79 y) from the British Regional Heart Study, free from CVD at baseline, were followed up for 11.3 y for CVD and mortality. Baseline food-frequency questionnaire data were used to generate 2 dietary scores: the Healthy Diet Indicator (HDI), based on WHO dietary guidelines, and the Elderly Dietary Index (EDI), based on a Mediterranean-style dietary intake, with higher scores indicating greater compliance with dietary recommendations. Cox proportional hazards regression analyses assessed associations between quartiles of HDI and EDI and risk of all-cause mortality, CVD mortality, CVD events, and coronary heart disease (CHD) events. During follow-up, 933 deaths, 327 CVD deaths, 582 CVD events, and 307 CHD events occurred. Men in the highest compared with the lowest EDI quartile had significantly lower risks of all-cause mortality (HR: 0.75; 95% CI: 0.60, 0.94; *P*-trend = 0.03), CVD mortality (HR: 0.63; 95% CI: 0.42, 0.94; *P*-trend = 0.03), and CHD events (HR: 0.66; 95% CI: 0.45, 0.97; *P*-trend = 0.05) but not CVD events (HR: 0.79; 95% CI: 0.60, 1.05; *P*-trend = 0.16) after adjustment for sociodemographic, behavioral, and cardiovascular risk factors. The HDI was not significantly associated with any of the outcomes. The EDI appears to be more useful than the HDI for assessing diet quality in relation to CVD and morality risk in older men. Encouraging older adults to adhere to the guidelines inherent in the EDI criteria may have public health benefits. J. Nutr. 144: 673–680, 2014.

Introduction

Historically, research into the relations between diet and cardiovascular disease (CVD)[6] or mortality has focused on single food items or nutrients, but more recently the focus has shifted toward markers of overall diet quality and dietary patterns to reflect the multidimensional nature of diets consumed in the population (1,2). Diet quality is a major modifiable risk factor well established in the prevention of CVD and mortality and may be particularly important in the elderly, a group at high risk of chronic disease (3–5). Several a priori–defined dietary scores have been developed to assess diet quality based on adherence to dietary patterns or recommendations (6,7). Although several studies have examined the associations between diet quality and CVD risk in middle age, few studies have investigated the relation between overall diet quality and health outcomes specifically in older adults (8–11).

The Healthy Diet Indicator (HDI) is one such a priori–defined dietary score, based on adherence to WHO nutrient intake guidelines, and has been shown to be inversely associated with all-cause mortality risk in older European men (12). One of the most commonly researched predefined dietary patterns is the Mediterranean diet score (MDS), characterized by a high consumption of fruit, vegetables, legumes, cereal, and fish and a low to moderate consumption of meat, dairy products, and alcohol, mostly as wine. Adherence to the MDS has been consistently associated with a lower risk of CVD and mortality in European cohorts (8,9,13,14). However, the MDS uses a dichotomous scoring system based on a cutoff of the median

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[3] Supplemental Tables 1 and 2 and Supplemental Figures 1 and 2 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.
[6] Abbreviations used: CHD, coronary heart disease; CRP, C-reactive protein; CVD, cardiovascular disease; EDI, Elderly Dietary Index; HDI, Healthy Diet Indicator; ICD-9, International Classification of Diseases, Ninth Revision; MDS, Mediterranean diet score; MI, myocardial infarction; SBP, systolic blood pressure; vWF, von Willebrand factor.
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intake of foods, and thus may be too crude to apply to a UK population who have previously been shown to have low adherence to Mediterranean-style dietary patterns (15). The Elderly Dietary Index (EDI) was originally developed as a slightly modified version of the MDS based on the frequency of consumption of specific foods or food groups, but it was developed specifically to address adherence to nutritional recommendations for older adults (16). The EDI uses a 4-point scoring system for each food component and takes into consideration the U-shaped relation between certain food items and the risk of health outcomes. The EDI may therefore be more suited to an older UK population in whom adherence to Mediterranean-style dietary components is low.

Most studies examining the associations between diet quality and health outcomes in the elderly have focused on all-cause mortality, and a recent review suggested that scores that reflect adherence to dietary recommendations based on single nutrients, such as the HDI, were not as strongly associated with mortality as other scores based on whole foods or patterns, such as the MDS (11–13). Fewer studies of diet quality in the elderly have provided evidence on associations with the risk of cardiovascular outcomes (10). The EDI has been shown to be associated with CVD risk factors in the Mediterranean population in whom it was developed, but, to our knowledge, the EDI has not been applied to other populations or compared with more widely used dietary indices such as the HDI, which uses a fundamentally different approach to assessing diet quality. The HDI is based on adherence to international dietary recommendations (WHO nutrient intake guidelines), so it has been used universally and would therefore make a useful comparison to the EDI. The aim of this study was therefore to examine existing dietary patterns that have been shown to have a protective effect on CVD and mortality and to investigate which marker of diet quality would be most applicable to an older UK population. We prospectively investigated the associations of diet quality comparing 2 predefined dietary scores (the HDI and the EDI) and the risk of CVD and all-cause mortality in a cohort of older British men.

Participants and Methods

Study population. The British Regional Heart Study is a prospective study in a socioeconomically and geographically representative sample of 7735 British men from 24 towns in Great Britain (17). The cohort is predominantly of white European ethnic origin (>99%) and was initially examined in 1978–1980. Twenty years later, in 1998–2000, 4252 men aged 60–79 y (77% of survivors) attended a physical examination, provided a fasting blood sample, and completed both a general lifestyle questionnaire and an FFQ (18). Of these 4252 men, 3328 participants free from prevalent myocardial infarction (MI), stroke, and heart failure at baseline and with available data on HDI or EDI scores were included in this study and followed up for morbidity and mortality until 2010. All participants provided written informed consent in accordance with the Declaration of Helsinki. Ethical approval was also obtained from relevant local research ethics committees.

Dietary assessment. Dietary intake was measured at baseline in 1998–2000 with a self-administered FFQ that was developed for use in the WHO's Monitoring Trends and Determinants in Cardiovascular Disease Survey (19) and has been validated against weighed food intake in British populations (20,21). Participants reported how frequently they usually ate 86 different food and drink items per week. Consumption frequencies were reported in 9 categories: 1, 2, 3, 4, 5, 6, or 7 d/wk; monthly; or rarely/never. Total macro- and micronutrient intakes of foods consumed were derived by using a validated computer program to calculate the total nutrient composition of all foods reported as consumed in the FFQ. This computer program multiplied the food frequency by the standard portion sizes for each food and by the nutrient composition of the food obtained from the UK food composition tables (22).

Dietary scores. We examined diet quality by using 2 predefined dietary scores. The HDI was constructed by using WHO dietary guidelines (4) for the intake of nutrients and food components, as initially used by Huijbregts et al. (12). The HDI consists of 8 components (SFAs, PUFAs, protein, carbohydrates, sugar, fiber, cholesterol, and fruit and vegetables), each scoring 1 if the dietary guideline was met and zero otherwise, resulting in a total score range from 0 to 8 (**Supplemental Table 1**). Dietary data for pulses, nuts, and seeds were unavailable, so this component could not be included in the HDI. The cutoff points for PUFAs and fiber intake were modified for use in a British population, as done previously (23,24). The weight of fruit and vegetables consumed was not available, so this component was modified from the recommendation of ≥400 g/d to the consumption of both fruit and vegetables daily (consumption frequency of 7 d/wk).

The EDI was developed by Kourlaba et al. (16) specifically to address adherence to nutritional recommendations for older adults on the basis of the frequency of consumption of specific foods/food groups in the Modified MyPyramid for Older Adults. The EDI consists of 9 components (meat, fish and seafood, legumes, fruit, vegetables, cereals, bread, olive oil, and dairy), each assigned a 4-point scoring system on the basis of frequency of consumption, resulting in a total score range from 9 to 36 (**Supplemental Table 2**). The frequency of olive oil consumption was not available, so the scoring of this component was modified using never/rarely consumed and tertiles of weekly consumption. The EDI was limited to food items to make it more comparable to the HDI, and therefore an alcohol component (frequency of wine consumption) was not included. Alcohol was included as an additional component of the EDI for sensitivity analysis only. Higher scores on both the HDI and EDI indicated greater compliance with dietary recommendations and hence a healthier diet. Participants were categorized into quartiles of HDI and EDI. However, due to the distribution of HDI and EDI, equally sized groups could not be created. (See **Supplemental Figs. 1** and **2** for the distribution of HDI and EDI, respectively.)

Comparative analysis. For comparative purposes, we also applied the modified MDS as initially developed by Trichopoulou et al. (13,14). The MDS consists of 8 components with a total score range from 0 to 8. Participants whose consumption of beneficial components (vegetables, legumes, fruit, cereals, fish, ratio of the sum of MUFAs and PUFAs to SFAs) was below the median scored zero or otherwise a value of 1. Participants whose consumption of detrimental components (meat, dairy) was below the median scored 1 or otherwise a value of zero.

Covariates. Self-reported measures of cigarette smoking, physical activity, alcohol intake, and social class were collected via questionnaire, and measurements of height, weight, plasma HDL cholesterol, and systolic blood pressure (SBP) were measured at the 20th-year examination, as described (17,25–27). Men were classified into 4 cigarette-smoking groups (never smoked; long-term ex-smokers, >15 y; recent ex-smokers, ≤15 y; or current smokers) (27). Current physical activity was classified into 6 groups on the basis of exercise intensity and frequency (inactive, occasional, light, moderate, moderately vigorous, or vigorous) (25). Alcohol intake was classified into 5 groups on the basis of the number and frequency of alcoholic beverages consumed (none, occasional, light, moderate, or heavy) (26). Social class was split into 3 groups on the basis of the longest held occupation coded by using the Registrar General's occupational classification (manual, nonmanual, armed forces). BMI was calculated, and participants were classified into categories using WHO cutoffs (underweight, <18.5 kg/m^2; normal weight, 18.5–24.99 kg/m^2; overweight, 25–29.99 kg/m^2; or obese, ≥30 kg/m^2) (28). At the 20th-year examination, participants were classified as having prevalent diabetes if they had a previous diagnosis according to medical records or self-report. Plasma concentrations of 2 novel cardiovascular risk factors were also measured: C-reactive protein (CRP), an inflammatory marker, was assayed by ultrasensitive nephelometry, and von Willebrand factor (vWF), a marker of endothelial dysfunction, was measured with ELISAs, as detailed previously (25).

Outcome ascertainment. Participants free from prevalent MI, stroke, and heart failure at baseline were followed prospectively for incident

TABLE 1 Baseline characteristics of British Regional Heart Study participants by quartiles of HDI and EDI (1998–2000)[1]

	HDI quartile					EDI quartile				
	1 (0–2 points; *n* = 1164)	2 (3 points; *n* = 928)	3 (4 points; *n* = 728)	4 (5–7 points; *n* = 313)	*P*-trend	1 (12–22 points; *n* = 897)	2 (23–24 points; *n* = 840)	3 (25–26 points; *n* = 774)	4 (27–35 points; *n* = 778)	*P*-trend
Median HDI or EDI score	2	3	4	5		21	24	26	28	
Age, *y*	68.3 ± 5.5	68.2 ± 5.5	68.4 ± 5.3	67.5 ± 5.0	0.16	68.5 ± 5.4	68.3 ± 5.5	68.3 ± 5.6	67.9 ± 5.2	0.02
Energy intake, *kcal/d*	2240 ± 601	2140 ± 530	2050 ± 432	2000 ± 395	<0.001	2160 ± 575	2190 ± 540	2160 ± 542	2050 ± 442	<0.001
Current smokers, *%*	16.2	12.1	8.7	7.1	<0.001	25.7	11.6	7.3	4.5	<0.001
Heavy drinkers, *%*	3.9	2.2	2.1	2.3	0.02	4.1	3.0	2.9	1.4	0.002
Physically inactive, *%*	10.4	8.7	9.5	7.7	0.20	13.4	8.6	8.4	7.5	<0.001
Manual social class, *%*	50.5	49.7	44.6	48.6	0.04	64.7	53.3	40.5	35.9	<0.001
Obese (BMI >30 kg/m^2), *%*	18.4	15.4	13.6	13.8	0.004	17.4	17.6	16.5	12.7	0.009
Diabetes, *%*	6.5	6.5	5.9	5.0	0.33	3.9	4.8	7.7	8.6	<0.001
SBP, *mm Hg*	150.3 ± 23.6	149.8 ± 24.5	149.4 ± 23.7	150.0 ± 23.3	0.56	149.9 ± 24.3	150.4 ± 23.9	150.5 ± 23.4	149.3 ± 23.8	0.65
Plasma HDL-C, *mmol/L*	1.4 ± 0.3	1.3 ± 0.3	1.3 ± 0.3	1.3 ± 0.3	0.006	1.3 ± 0.4	1.3 ± 0.3	1.4 ± 0.3	1.3 ± 0.3	0.34
Plasma CRP,[2] *mg/L*	1.7 (0.9–3.4)	1.6 (0.7–3.2)	1.6 (0.7–3.2)	1.4 (0.6–2.8)	0.01	2.0 (0.9–4.2)	1.7 (0.8–3.4)	1.5 (0.7–3.0)	1.3 (0.6–2.4)	<0.001
Plasma vWF, *IU/dL*	137 ± 45.2	135 ± 44.9	138 ± 45.3	135 ± 43.8	0.76	140 ± 45.6	138 ± 44.3	135 ± 45.2	132 ± 45.1	<0.001

[1] Values are means ± SDs or percentages unless otherwise specified. CRP, C-reactive protein; EDI, Elderly Dietary Index; HDI, Healthy Diet Indicator; HDL-C, HDL cholesterol; SBP, systolic blood pressure; vWF, von Willebrand factor.
[2] Log-transformed values [geometric means (IQRs)] are presented.

cardiovascular morbidity and mortality to June 2010 (29). All men were followed up for mortality, and follow-up was achieved for 98% of the cohort for morbidity. Information on death was collected through National Health Service Central Registers [death certificates coded by using the International Classification of Diseases, Ninth Revision (ICD-9)]. Fatal coronary heart disease (CHD) was defined as ICD-9 codes 410–414, fatal stroke was defined as ICD-9 codes 430–438, and fatal CVD was defined as ICD-9 codes 390–459. A nonfatal MI was diagnosed according to WHO criteria (30). Nonfatal stroke events were those that produced a neurologic deficit that was present for >24 h, which is also in accordance with WHO criteria (30). Evidence regarding nonfatal MI and nonfatal stroke was obtained by ad hoc reports from general practitioners supplemented by a 2-yearly review of the patients' practice records, including clinic and hospital correspondence (18). The 4 main outcome measures assessed in this study were as follows: CHD events (defined as nonfatal MI or fatal CHD), CVD events (defined as nonfatal MI, nonfatal stroke, or fatal CVD), CVD mortality, and all-cause mortality. In further exploratory analysis, 2 additional outcomes were considered: stroke events (defined as nonfatal or fatal stroke) and non-CVD mortality (all deaths excluding ICD-9 codes 390–459).

Statistical analysis. Of the 3529 men free from prevalent CVD, 3328 had adequate data to generate either the HDI or EDI scores (n = 3133 and n = 3269, respectively). Sensitivity analyses were carried out, restricting the sample to those for whom both HDI and EDI measures were available (n = 3074). However, the results were largely unchanged, so individuals with data on either HDI or EDI were kept in the final analysis to maximize the sample size. Baseline characteristics of participants were presented by quartiles of HDI and EDI with continuous variables reported as means and SDs and categorical variables as percentages. The distribution of CRP was highly skewed so log transformation and geometric means were used. Cox proportional hazards models were used to estimate HRs and 95% CIs for the associations between individual components of the HDI/EDI scores with the risk of outcomes, adjusting for age (model 1) and energy intake, smoking status, alcohol intake, physical activity, social class, BMI, and a modified version of the HDI/EDI score, not containing the individual component of interest (model 2). Cox proportional hazards models were also used to assess associations between quartiles of the total HDI/EDI scores with the risk of outcomes. Tests for trend of outcome risk across quartiles of HDI/EDI were performed. Similarly, comparative analyses were carried out to assess associations between quartiles of the total MDS with the risk of outcomes. All Cox models were tested for the proportional hazards assumption, which was not found to be violated. Models were adjusted by adding potential confounders in a sequential manner, including the following: age (model 1); energy intake, smoking status, alcohol intake, physical activity, social class, and BMI (model 2); HDL cholesterol, SBP, and diabetes (model 3); and CRP and vWF (model 4). Age, energy intake, HDL cholesterol, SBP, CRP, and vWF were fitted as continuous variables. Smoking status, alcohol intake, physical activity, social class, BMI, and diabetes were fitted as categorical variables. All analyses were performed in Stata 12.1.

Results

During a mean follow-up period of 11.3 y, of the 3328 men free from prevalent CVD included in the analysis there were 933 deaths from all causes, 327 CVD deaths, 582 CVD events, and 307 CHD events. The mean HDI score was 2.9, ranging from 0 to 7 (Supplemental Fig. 1), and the mean EDI score was 24.2, ranging from 12 to 35 (Supplemental Fig. 2). Only 18.1% of the cohort consumed fresh fruit and vegetables daily. HDI and EDI scores were significantly, but modestly, correlated (r = 0.25; 95% CI: 0.22, 0.29; P < 0.001). Baseline characteristics of participants by quartiles of HDI and EDI are presented in **Table 1**. Men with a higher adherence to both HDI and EDI dietary recommendations were significantly less likely to be current smokers, heavy drinkers, manual social class, or obese and had lower total

TABLE 2 HRs (95% CIs) for associations between quartiles of total HDI score and risk of all-cause mortality, CVD mortality, CVD events, and CHD events in British Regional Heart Study participants from baseline (1998–2000) to 2010[1]

	Cases	Rate	Model 1	Model 2	Model 3	Model 4
	n	*per 1000 person-years*				
All-cause mortality						
Q1	327	28.47	1.00	1.00	1.00	1.00
Q2	249	26.97	0.94 (0.80, 1.11)	1.00 (0.84, 1.19)	1.06 (0.89, 1.28)	1.06 (0.89, 1.28)
Q3	209	29.17	1.03 (0.86, 1.22)	1.11 (0.92, 1.33)	1.18 (0.97, 1.44)	1.17 (0.96, 1.42)
Q4	72	22.73	0.91 (0.70, 1.17)	0.94 (0.71, 1.23)	1.01 (0.75, 1.34)	0.96 (0.72, 1.29)
P-trend			0.77	0.72	0.31	0.46
CVD mortality						
Q1	118	10.27	1.00	1.00	1.00	1.00
Q2	83	8.99	0.87 (0.66, 1.16)	0.91 (0.68, 1.23)	1.02 (0.75, 1.39)	1.03 (0.75, 1.41)
Q3	69	9.63	0.95 (0.70, 1.27)	1.03 (0.75, 1.41)	1.11 (0.79, 1.55)	1.12 (0.80, 1.58)
Q4	23	7.26	0.85 (0.54, 1.33)	0.84 (0.51, 1.38)	0.94 (0.56, 1.59)	0.84 (0.49, 1.43)
P-trend			0.49	0.74	0.83	0.98
CVD events						
Q1	197	17.82	1.00	1.00	1.00	1.00
Q2	155	17.48	0.98 (0.79, 1.20)	1.00 (0.80, 1.25)	1.07 (0.85, 1.34)	1.07 (0.85, 1.35)
Q3	142	20.98	1.18 (0.95, 1.47)	1.27 (1.01, 1.60)*	1.28 (1.01, 1.64)*	1.27 (0.99, 1.62)
Q4	44	14.49	0.90 (0.65, 1.25)	0.88 (0.62, 1.27)	0.92 (0.64, 1.34)	0.89 (0.61, 1.31)
P-trend			0.62	0.43	0.35	0.45
CHD events						
Q1	101	8.96	1.00	1.00	1.00	1.00
Q2	75	8.27	0.92 (0.68, 1.24)	0.92 (0.67, 1.25)	0.97 (0.70, 1.35)	0.99 (0.71, 1.37)
Q3	78	11.18	1.25 (0.93, 1.67)	1.31 (0.96, 1.79)	1.33 (0.95, 1.85)	1.35 (0.97, 1.89)
Q4	32	10.32	1.26 (0.85, 1.88)	1.21 (0.78, 1.87)	1.31 (0.83, 2.07)	1.28 (0.81, 2.04)
P-trend			0.10	0.10	0.08	0.08

[1] $n = 3133$. Model 1 adjusted for age; model 2 adjusted as in model 1 plus energy intake, smoking, alcohol, physical activity, social class, and BMI; model 3 adjusted as in model 2 plus HDL cholesterol, systolic blood pressure, and diabetes; model 4 adjusted as in model 3 plus C-reactive protein and von Willebrand factor. *$P < 0.05$. CHD, coronary heart disease; CVD, cardiovascular disease; HDI, Healthy Diet Indicator; Q, quartile.

energy intakes and CRP. In addition, those with higher EDI scores were significantly more likely to be younger, physically active, have diabetes, and have lower concentrations of vWF. Those with higher HDI scores had significantly lower HDL-cholesterol concentrations.

No significant trends were seen between quartiles of total HDI score and all-cause mortality, CVD mortality, CVD events, or CHD events after adjustment for age (**Table 2**). The lack of association was still present after further adjustment for sociodemographic, behavioral, and cardiovascular risk factors. A significant association was seen between EDI quartiles and all-cause mortality, which remained but was attenuated slightly after adjustment for sociodemographic, behavioral, and cardiovascular risk factors (**Table 3**). The risk of all-cause mortality tended to decrease with increased EDI score; and in the fully adjusted model (model 4), the risk of all-cause mortality was significantly lower in participants in the highest compared with those in the lowest EDI quartile (HR: 0.75; 95% CI: 0.60, 0.94; *P*-trend = 0.03). Similarly, participants in the highest quartile of EDI had a significantly lower risk of CVD mortality (HR: 0.63; 95% CI: 0.42, 0.94; *P*-trend = 0.03) and CHD events (HR: 0.66; 95% CI: 0.45, 0.97; *P*-trend = 0.05) in the fully adjusted model. However, the risk of CVD events was not significantly associated with EDI quartiles after adjustment for confounders (HR: 0.79; 95% CI: 0.60, 1.05; *P*-trend = 0.16). Further exploration of the data showed that there was also a lack of association between EDI quartiles and stroke events (age-adjusted *P*-trend = 0.41), which may explain the observed association of EDI with CVD mortality and CHD events but not with CVD events. Additional analysis of mortality by cause showed that the risk of non-CVD mortality was not significantly associated with EDI quartiles after adjusting for confounders (*P*-trend = 0.24).

A sensitivity analysis including alcohol as an additional component of the EDI yielded broadly similar results (data not shown). Risks of outcomes tended to decrease with increasing EDI scores, with men in the highest compared with the lowest EDI quartile having lower risks of all-cause (HR: 0.71; 95% CI: 0.55, 0.91; *P*-trend = 0.02) and CVD (HR: 0.58; 95% CI: 0.37, 0.91; *P*-trend = 0.03) mortality, after adjustment for sociodemographic, behavioral, and cardiovascular risk factors. However, this trend was weaker for CVD (HR: 0.70; 95% CI: 0.51, 0.96; *P*-trend = 0.06) and CHD (HR: 0.66; 95% CI: 0.43, 1.02; *P*-trend = 0.08) events.

Comparative analyses using the MDS yielded weaker associations compared with the EDI (data not shown). There was a borderline significant trend between increasing MDS quartiles and decreasing mortality risk (*P*-trend = 0.05) after adjustment for sociodemographic, behavioral, and cardiovascular risk factors. However, there was no significant trend between MDS quartiles and risk of CVD mortality (*P*-trend = 0.40), CVD events (*P*-trend = 0.97), or CHD events (*P*-trend = 0.57).

We also investigated the associations between individual HDI and EDI components (first adjusted for age and then additionally for sociodemographic and behavioral risk factors and a modified version of the HDI/EDI score not containing the individual component of interest) and a range of outcomes (**Table 4**). Very few individual components related to outcomes. For the HDI components, meeting the dietary guideline for cholesterol was significantly related to lower CVD mortality risk. For the individual EDI components, having the highest olive oil score,

TABLE 3 HRs (95% CIs) for associations between quartiles of total EDI score and risk of all-cause mortality, CVD mortality, CVD events, and CHD events in British Regional Heart Study participants from baseline (1998–2000) to 2010[1]

	Cases	Rate	Model 1	Model 2	Model 3	Model 4
	n	*per 1000 person-years*				
All-cause mortality						
Q1	314	37.28	1.00	1.00	1.00	1.00
Q2	233	28.06	0.75 (0.63, 0.89)*	0.88 (0.73, 1.06)	0.85 (0.70, 1.03)	0.85 (0.70, 1.03)
Q3	200	26.86	0.72 (0.60, 0.86)*	0.89 (0.74, 1.09)	0.88 (0.72, 1.08)	0.89 (0.72, 1.10)
Q4	160	19.69	0.55 (0.46, 0.67)*	0.74 (0.60, 0.91)*	0.73 (0.59, 0.92)*	0.75 (0.60, 0.94)*
P-trend			<0.001	0.01	0.01	0.03
CVD mortality						
Q1	115	13.65	1.00	1.00	1.00	1.00
Q2	85	10.24	0.75 (0.57, 1.00)*	0.87 (0.64, 1.18)	0.80 (0.58, 1.12)	0.79 (0.57, 1.10)
Q3	69	9.27	0.68 (0.50, 0.91)*	0.79 (0.57, 1.10)	0.78 (0.55, 1.11)	0.79 (0.55, 1.13)
Q4	48	5.91	0.47 (0.33, 0.66)*	0.60 (0.41, 0.88)*	0.60 (0.41, 0.90)*	0.63 (0.42, 0.94)*
P-trend			<0.001	0.008	0.02	0.03
CVD events						
Q1	181	22.42	1.00	1.00	1.00	1.00
Q2	145	18.17	0.81 (0.65, 1.01)	0.88 (0.70, 1.12)	0.85 (0.66, 1.08)	0.84 (0.66, 1.08)
Q3	126	17.70	0.80 (0.64, 1.00)	0.91 (0.71, 1.16)	0.89 (0.69, 1.16)	0.91 (0.70, 1.18)
Q4	118	15.22	0.71 (0.56, 0.90)*	0.82 (0.63, 1.07)	0.79 (0.60, 1.04)	0.79 (0.60, 1.05)
P-trend			0.01	0.17	0.14	0.16
CHD events						
Q1	104	12.67	1.00	1.00	1.00	1.00
Q2	77	9.47	0.75 (0.56, 1.01)	0.81 (0.59, 1.11)	0.75 (0.54, 1.05)	0.75 (0.54, 1.06)
Q3	66	9.03	0.72 (0.53, 0.98)*	0.80 (0.57, 1.12)	0.79 (0.55, 1.12)	0.80 (0.56, 1.14)
Q4	54	6.74	0.56 (0.40, 0.78)*	0.64 (0.44, 0.92)*	0.64 (0.44, 0.94)*	0.66 (0.45, 0.97)*
P-trend			0.001	0.02	0.03	0.05

[1] $n = 3269$. Model 1 adjusted for age; model 2 adjusted as in model 1 plus energy intake, smoking, alcohol, physical activity, social class, and BMI; model 3 adjusted as in model 2 plus HDL cholesterol, systolic blood pressure, and diabetes; model 4 adjusted as in model 3 plus C-reactive protein and von Willebrand factor. *$P < 0.05$. CHD, coronary heart disease; CVD, cardiovascular disease; EDI, Elderly Dietary Index; Q, quartile.

compared with the lowest score, was associated with a significantly lower risk of all outcomes.

Discussion

This study investigated the association between 2 predefined diet quality scores and the risk of CVD and all-cause mortality in a prospective cohort of older British men and adds to the limited literature on diet quality and health outcomes in older adults. We have applied the HDI (based on WHO dietary recommendations) and the EDI (based on the consumption frequency of specific foods/food groups) to an older British population, showing that men with higher adherence to EDI dietary recommendations had a significantly lower risk of all-cause mortality, CVD mortality, and CHD events, which was independent of sociodemographic, behavioral, and cardiovascular risk factors. However, the HDI score was not significantly associated with any of the outcome measures, suggesting that the EDI may be a more useful diet quality assessment tool for predicting the risk of CHD events, CVD mortality, and all-cause mortality in an older population.

The HDI, CVD, and mortality risk. The HDI score used in this study was initially developed by Huijbregts et al. (12) who, in contrast to our findings, found a significant inverse association between HDI and mortality risk and an even stronger association with CVD mortality risk over 20 y of follow-up in elderly men from Finland, Italy, and The Netherlands. However, our findings are in keeping with those from an elderly British cohort, which showed no significant association between a slightly modified version of the HDI and all-cause mortality during 14 y of follow-up (24), and from an elderly male Swedish cohort, which showed no consistent associations between HDI and total or CVD mortality (31).

The EDI, CVD, and mortality risk. The EDI was originally developed by Kourlaba et al. (16) and showed cross-sectional associations with CVD risk factors including obesity and hypertension in the Mediterranean Islands Study. Our finding revealed that only 1 individual component of the EDI (olive oil intake) was associated with CVD outcomes and mortality. However, we found a significant trend between increasing EDI score and decreasing risk of CHD events, CVD mortality, and all-cause mortality. To our knowledge, this is the first study to apply the EDI to another population and to examine the incidence of cardiovascular events by EDI score. Our results are consistent with, but an extension to, initial findings by Kourlaba et al., suggesting that the EDI is valid to use in an older British population and that high adherence to the EDI showed significant reductions in all-cause mortality, CVD mortality, and CHD events.

Our results are consistent with a substantial body of literature showing strong associations between a Mediterranean-style diet and lower risk of CVD and all-cause mortality in both middle-aged and elderly populations (8–10,13,32). Associations observed between the EDI and CHD events, CVD mortality, and all-cause mortality were attenuated slightly, although still significant, after adjustment for variables including BMI, HDL cholesterol, SBP, diabetes, CRP, and vWF. Cardiovascular risk factors, including inflammation, may therefore be partly mediating the relation between diet quality and CVD or mortality, as suggested

TABLE 4 HRs (95% CIs) for associations between HDI and EDI components and all-cause mortality, CVD mortality, CVD events, and CHD events in British Regional Heart Study participants from baseline (1998–2000) to 2010[1]

			All-cause mortality		CVD mortality		CVD events		CHD events	
	n[2]	%	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
HDI components[3]										
Did not meet guideline (score = 0)			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Met guideline (score = 1)										
SFAs	790	25.2	1.05 (0.90, 1.23)	1.14 (0.96, 1.36)	1.10 (0.83, 1.44)	1.28 (0.94, 1.72)	1.06 (0.87, 1.30)	1.15 (0.92, 1.43)	1.09 (0.84, 1.43)	1.14 (0.85, 1.53)
PUFAs	458	14.6	1.14 (0.95, 1.37)	1.15 (0.95, 1.39)	1.29 (0.95, 1.73)	1.30 (0.95, 1.78)	1.13 (0.90, 1.43)	1.09 (0.86, 1.39)	1.28 (0.95, 1.74)	1.27 (0.93, 1.75)
Protein	1298	41.4	1.19 (1.04, 1.36)*	1.11 (0.95, 1.29)	1.18 (0.93, 1.48)	1.06 (0.82, 1.37)	1.17 (0.99, 1.39)	1.07 (0.89, 1.30)	1.28 (1.01, 1.61)*	1.15 (0.89, 1.48)
Carbohydrates	2024	64.6	0.94 (0.82, 1.08)	0.93 (0.79, 1.09)	0.98 (0.77, 1.25)	0.90 (0.69, 1.19)	1.12 (0.93, 1.34)	1.01 (0.83, 1.24)	1.23 (0.96, 1.58)	1.05 (0.79, 1.38)
Sugar	39	1.2	1.25 (0.69, 2.27)	1.10 (0.58, 2.06)	0.73 (0.18, 2.92)	0.79 (0.20, 3.22)	0.51 (0.16, 1.59)	0.56 (0.18, 1.77)	0.64 (0.16, 2.58)	0.73 (0.18, 2.95)
Fiber	1920	61.3	1.00 (0.87, 1.14)	1.04 (0.90, 1.20)	0.92 (0.73, 1.16)	1.02 (0.80, 1.31)	0.95 (0.80, 1.13)	1.06 (0.88, 1.27)	1.20 (0.94, 1.53)	1.32 (1.02, 1.70)
Cholesterol	2017	64.4	0.91 (0.79, 1.04)	0.88 (0.74, 1.04)	0.73 (0.58, 0.92)*	0.67 (0.50, 0.90)*	0.90 (0.76, 1.08)	0.90 (0.72, 1.12)	0.87 (0.68, 1.10)	0.78 (0.58, 1.05)
Fruit and vegetables	568	18.1	0.80 (0.67, 0.97)*	0.92 (0.75, 1.11)	0.83 (0.61, 1.14)	0.92 (0.66, 1.28)	0.91 (0.73, 1.13)	1.01 (0.80, 1.28)	0.90 (0.66, 1.22)	1.01 (0.74, 1.39)
EDI components[4]										
Lowest compliance with guideline (score = 1)			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Highest compliance with guideline (score = 4)										
Meat	159	4.9	0.90 (0.65, 1.23)	1.11 (0.79, 1.55)	0.64 (0.34, 1.21)	0.92 (0.49, 1.75)	0.63 (0.40, 1.01)	0.75 (0.46, 1.22)	0.59 (0.30, 1.14)	0.73 (0.38, 1.44)
Fish/seafood	1832	56.0	0.76 (0.53, 1.09)	0.91 (0.62, 1.34)	0.53 (0.31, 0.91)*	0.66 (0.36, 1.21)	0.75 (0.48, 1.16)	0.85 (0.52, 1.37)	0.54 (0.32, 0.94)*	0.67 (0.37, 1.21)
Legumes	1653	50.6	0.85 (0.69, 1.03)	0.91 (0.74, 1.13)	0.81 (0.58, 1.13)	0.83 (0.58, 1.19)	0.92 (0.71, 1.21)	0.94 (0.71, 1.24)	0.83 (0.59, 1.18)	0.89 (0.61, 1.30)
Fruit	1298	39.7	0.61 (0.48, 0.76)*	0.86 (0.66,1.11)	0.67 (0.45, 1.02)	0.95 (0.59, 1.53)	0.75 (0.55, 1.01)	0.90 (0.64, 1.28)	0.68 (0.45, 1.03)	0.86 (0.54, 1.35)
Vegetables	930	28.5	0.67 (0.47, 0.96)*	1.05 (0.70, 1.58)	0.63 (0.36, 1.12)	0.88 (0.47, 1.65)	0.84 (0.52, 1.35)	1.17 (0.69, 2.01)	0.89 (0.46, 1.72)	1.29 (0.65, 2.56)
Cereals	2151	65.8	0.86 (0.67, 1.10)	1.15 (0.87, 1.52)	1.10 (0.70, 1.72)	1.37 (0.83, 2.25)	1.08 (0.77, 1.51)	1.13 (0.79, 1.62)	0.99 (0.64, 1.53)	1.19 (0.73, 1.93)
Bread	934	28.6	0.67 (0.27, 1.62)	0.77 (0.32, 1.90)	0.55 (0.14, 2.24)	0.57 (0.14, 2.40)	0.57 (0.21, 1.54)	0.60 (0.22, 1.65)	0.62 (0.15, 2.52)	0.76 (0.18, 3.15)
Olive oil	302	9.2	0.59 (0.45, 0.77)*	0.68 (0.51, 0.91)*	0.42 (0.24, 0.72)*	0.43 (0.24, 0.80)*	0.54 (0.37, 0.77)*	0.58 (0.40, 0.86)*	0.47 (0.28, 0.79)*	0.55 (0.32, 0.95)*
Dairy	424	13.0	1.07 (0.86, 1.32)	1.14 (0.90, 1.44)	1.00 (0.70, 1.45)	1.09 (0.73, 1.62)	1.04 (0.78, 1.37)	1.12 (0.83, 1.52)	0.95 (0.65, 1.39)	0.90 (0.59, 1.36)

[1] Model 1 adjusted for age; model 2 adjusted as in model 1 plus energy intake, smoking, alcohol, physical activity, social class, BMI, and a modified version of the HDI/EDI score not containing the individual component of interest. *$P < 0.05$. CHD, coronary heart disease; CVD, cardiovascular disease; EDI, Elderly Dietary Index; HDI, Healthy Diet Indicator.
[2] Number of participants who met the guideline (score = 1) for HDI or those who had the highest compliance with the guideline (score = 4) for EDI.
[3] HDI components: score 1 vs. score 0 (n = 3133).
[4] EDI components: score 4 vs. score 1 (n = 3269).

previously (33–35). Despite the association with CVD mortality, the EDI was not associated with CVD events, due to the lack of association with stroke events. This finding can be explained by the fact that fatal CVD was dominated by fatal CHD with far fewer fatal strokes and is in keeping with the literature, which suggests that adherence to a Mediterranean-style diet is more strongly associated with fatal CVD than total CVD (36).

In comparison to the EDI, the MDS showed a weaker association with all-cause mortality and no significant associations with CVD mortality, CVD events, and CHD mortality. EDI components are very similar to those of the MDS, but the EDI was developed specifically to address adherence to nutritional recommendations for older adults. The MDS uses dichotomous median cutoff values, which may not be appropriate for a population with low adherence to dietary guidelines, whereas the EDI uses a 4-point scoring range, which captures a wider range of intakes and also takes into account U-shaped relations that exist between some foods, such as meat, and disease risk (7,13,16). Our results show that the EDI may be more suited to an older UK population than the MDS, because it seemed to be a less crude Mediterranean diet quality measure for use in a population with low Mediterranean-style dietary adherence (15).

The EDI versus the HDI. This study suggests that diet quality scores based on specific foods or food groups, such as the EDI, may be a better predictor of CHD events, CVD mortality, and all-cause mortality in an older population compared with scores based on recommended nutrient intakes, such as the HDI. This is consistent with a recent review showing that a priori–defined scores based on nutrient dietary recommendations, such as the HDI, were not as strongly associated with mortality as scores based on whole foods or dietary patterns, such as the MDS or EDI (11). Our results may be explained by the fact that specific food/food groups are simpler to measure and less prone to measurement error compared with generating total dietary macro- and micronutrient intakes for the HDI, which assumes standard portion sizes of foods consumed and relies on having a food composition database that is complete and current (37). The lack of association observed between the HDI and outcomes may also represent insufficient variation in scoring due to homogeneity of the diet in this cohort. Furthermore, a critical review of predefined diet quality scores previously questioned the utility of diet quality indexes based on dietary guidelines, such as the HDI, and suggested that diet score ranges are preferable to simple cutoffs because they are more subtle (the EDI may be more nuanced than the HDI because it uses a 4-point as opposed to a dichotomous scoring system) and can take into account U-shaped correlations between foods and health outcomes (7). The EDI therefore seems to have practical advantages over the HDI because it is a more easily applicable tool for assessing diet quality among the elderly (16).

Strengths and limitations. The major strengths of this study are that it was a large, prospective, population-based study, with negligible loss to follow-up and objective ascertainment of CVD and mortality outcomes (29). Also, several potentially relevant confounding variables were considered. Dietary intake was assessed by using an FFQ that has previously been validated against weighed food intakes in British populations (20,21). FFQs are more prone to measurement error than other dietary measures such as 24-h dietary recall or weighted food records that have been collected multiple times. In addition, the FFQ measured dietary intake at 1 time point, so we do not know if people maintained dietary practices throughout the study period. Furthermore, in older populations, nonresponse to FFQ questions could have increased the chance of underreporting (37,38). However, all analyses were adjusted for total energy intake to reduce the risk of bias (39). We investigated older men of predominantly white European ethnic origin, so the extent to which results are generalizable to women and nonwhite ethnic groups is uncertain. Last, we cannot exclude the possibility of residual confounding, because self-reported variables such as smoking status, alcohol intake, and physical activity may have been subject to misclassification and other unmeasured confounding factors may have been present due to the observational nature of this study.

Conclusions. Older men with higher adherence to EDI dietary recommendations had a lower risk of all-cause mortality, CVD mortality, and CHD events, which was independent of sociodemographic, behavioral, and cardiovascular risk factors. The EDI may be a more useful tool for assessing diet quality in older men because it is a stronger predictor of CHD events, CVD mortality, and all-cause mortality risk compared with the HDI, which was not significantly associated with these outcomes. Among older men, the EDI is a better measure of a healthy diet than the HDI.

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