

ORIGINAL ARTICLE

Meat consumption and diet quality and mortality in NHANES III

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BACKGROUND/OBJECTIVES: There is growing evidence that meat consumption is associated with total and cause-specific mortality. Our objective was to evaluate the association of meat intake and the healthy eating index (HEI) with total mortality, cancer and cardiovascular disease (CVD) mortality.

SUBJECTS/METHODS: Analyses are based on 17 611 participants from Third National Health and Nutrition Examination Survey (NHANES III) (1986–2010). Meat intake was assessed using a food frequency questionnaire administered at baseline. Adherence to the HEI was analyzed with a single 24-h dietary recall. Cox proportional hazards regression models were used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) of mortality according to five categories of meat consumption and three categories of the HEI score.

RESULTS: During the follow-up period, 3683 deaths occurred, of which 1554 were due to CVD and 794 due to cancer. After multivariable adjustment, neither red and processed meat, nor white meat consumption were consistently associated with all-cause or cause-specific mortality. In men, white meat consumption tended to be inversely associated with total mortality (P for trend = 0.02), but there was no such association among women. Significantly decreased mortality was observed in the top compared with the bottom third of the HEI score (HR = 0.70, 95% CI 0.52–0.96). This association was only observed in men, but not in women.

CONCLUSIONS: Meat consumption was not associated with mortality. A healthy diet according to HEI, however, was associated with a decreased total mortality in men, but not in women.

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Keywords: cohort study; NHANES III; mortality; meat consumption; healthy eating index (HEI)

INTRODUCTION

Meat is a major source of animal protein and fat in many regions of the world.¹ Average annual consumption per person has increased by 12 kg during the period of 1966–1999 worldwide, and even more in specific regions like Latin America and the industrialized countries.² The rise of meat consumption will continue especially in developing countries.³ Based on several published meta-analyses, there is strong evidence that consumption of red meat and especially processed meat is associated with an increased risk of various cancers and CVD.^{4,5} Furthermore, there is evidence that elevated chronic disease mortality is linked to higher meat consumption becomes more frequent. Red meat has been associated with an increased risk of cardiovascular disease (CVD) and cancer by various studies.^{6–10} Two recent large cohort studies found significant association between increased intake of red meat and processed meat and increased risk of mortality.^{11,12} To enhance the evidence, we analyzed data from the Third National Health and Nutrition Examination Survey (NHANES III), a large, nationally representative study of the US population to investigate whether red, processed and white meat consumption increase the risk for total mortality as well as cause-specific mortality, including cancer and CVD mortality.

As an alternative approach to the single food group observation, we further analyzed the influence of overall diet quality on mortality by integrating the healthy eating index (HEI) score. The HEI score was developed by the US Department of Agriculture (as a monitoring tool for the diet quality of the US population).¹³

Data supporting the effectiveness for health improvement by the HEI are yet sparse; nevertheless, it is a very important policy tool to design future research interventions.^{14–18}

MATERIALS AND METHODS

Study population

NHANES III is a cross-sectional study conducted by the National Center for Health Statistics between 1988 and 1994.¹⁹ It was designed as a multistage stratified, clustered probability sample of the US civilian non-institutionalized population at least 2 months old. To ensure adequate sample sizes of specific subgroups of the US population, Mexican Americans, non-Hispanic blacks and the elderly were oversampled.¹⁹ In total, 33 944 individuals were interviewed in the NHANES III, including a food frequency questionnaire. In addition, an extensive physical examination, which included a blood sample and anthropometric assessments, was conducted in a mobile examination center. Detailed methods for the NHANES III baseline data collection have been described elsewhere.¹⁹

Dietary assessment

In an 81-item food frequency questionnaire completed at baseline, usual consumption of foods and drinks during the past month was assessed; however, portion size was not assessed. Red meat intake was calculated using the frequency of consumption of all types of beef, pork, ham, liver and other organ meats. White meat included chicken and turkey and processed meat included bacon, sausage and other processed meats. The category fish included only the item fish.

HEI scores

In 2000, the Centers for Disease Control and Prevention introduced the HEI as a measure for diet quality.²⁰ HEI score ranges from 0 to 100, with 10 equally weighted components, each with a score ranging from 0 to 10. The first five components of the HEI are based on the Food Guide Pyramid's recommended number of servings of grains, fruits, vegetables, meats and dairy products. A score of zero is assigned for zero servings and the maximum score indicates that the recommended servings were reached. Proportional scores were assigned to consumption levels between the minimum and maximum range.²¹ The next four components were adapted from the *Dietary Guidelines for Americans* considering the recommended intakes of total fat, saturated fat, cholesterol and sodium.²² A full score of 10 points each was matched for diets with <30% of energy from fat, <10% of energy from saturated fat, <300 mg cholesterol and <2400 mg sodium. The last component measures the dietary variety. In our analysis, the data on which the HEI score is based were derived from a single 24-h dietary recall using an automated, interactive interview.²³

Mortality follow-up

Mortality status for participants was tracked through 31 December 2010. Vital status was ascertained by the National Center for Health Statistics through a rigorous process of probabilistic matching and death certificate review based on seven matching criteria including Social Security number, name, gender and date of birth.²⁴ The follow-up period for each study participant was calculated as the time from their NHANES III examination to either a mortal event or the censoring date. Based on the National Death Index, data underlying cause of death were used for case definition according to the ICD-9 through 1998, and the remainder according to ICD-10. Cardiovascular mortality was defined by any of the ICD-9 codes 390–434 and 436–459 and ICD-10 codes I00–I99. Cancer mortality was defined by ICD-9 codes 140–239 and ICD-10 codes C00–C34, C37–C41, C43–C49, C50–C52, C54–C65, C67–C80, C82–C85, C88, C90–C95 and C97. All-cause mortality included all specified causes as well as unknown cause.

Statistical analysis

For this study, we included all participants who were 18 years of age or older at the examination and from whom mortality data were available. We excluded individuals who had a history of myocardial infarction, stroke, heart failure or cancer ($n = 2353$). We further excluded individuals whose questionnaire had missing answers for meat consumption ($n = 86$). After all exclusions, our analytic cohort consists of 8239 men and 9372 women.

We used time-dependent Cox proportional hazards regression models to estimate hazard ratios (HRs) and 95% confidence intervals (CIs). The entire cohort was divided into categories of red meat, processed meat, white meat and fish consumption, and multivariate-adjusted HRs are reported using the lowest category as the referent category. The cut-points for the groups were as follows: red meat: 6; 14; 29; 44 times/month; processed meat: 0; 6; 14; 29 times/month; white meat: 0; 3; 8; 12 times/month; fish: 0; 2; 4; 8; times/month. For the HEI score, participants were divided into the three groups as follows: *good* (a score of 81 and more), *needs improvement* (a score between 51 and 80) and *poor* (a score of 50 or less) according to the recommended HEI criteria by Bowman *et al.*²¹ Variables that were examined as potential confounders for the association of meat consumption with mortality included age (continuous), race (non-Hispanic white, non-Hispanic black, Mexican-American, other), sex, cigarette smoking (never, former, current (1–19 cigarettes/day; 20–39 cigarettes/day; 40+ cigarettes/day); missing), alcohol consumption (none, 1–4, 5–29, 30+ times/month), physical activity (none, 0 to <2 to <4 to <6, >6 times/week), socioeconomic status (poor, near poor, middle income, higher income; based on the poverty income ratio), body mass index (BMI) (continuous; calculated as weight in kilograms divided by height in meters squared), marital status (married/living together; never married/widowed; divorced/separated; missing), fruit and vegetables intake (quartiles of intake), history of hypertension, diabetes, hypercholesterolemia, use of aspirin and ibuprofen, use of mineral and vitamin supplements and family history of diabetes or hypercholesterolemia. In women, we also adjusted for hormone replacement therapy and oral contraceptive use.

Trend tests were performed by assigning to each subject the median value for the consumption category^{1–5} into which the subject fell and modeling this term as a continuous variable, the coefficient for which was evaluated by the Wald test. We tested for interaction between sex and meat or fish consumption by including a cross-product term along with

the main effect terms in the Cox regression model. The statistical significance of the cross-product terms was evaluated using the Wald test.

All statistical analyses were performed using SUDAAN as implemented in SAS v.9.2 (Cary, NC, USA).

RESULTS

Meat consumption

During 22 years of follow-up, there were 1908 male and 1775 female deaths summing up to 3683 recorded deaths, of which 1554 were due to CVD and 794 due to cancer. Participants with higher intake of red meat tended to also consume more processed meat but slightly less fish. In general, participants who consumed more red meat tended to be younger and less active, to have rather a normal blood pressure, to take less dietary supplements, smoke more, have a lower BMI and waist circumference and eat more vegetable but less fruits compared with participants who ate less red meat (Table 1).

High red and processed meat consumption was significantly associated with increased total mortality in the model adjusted for age, sex and race/ethnicity (red meat HR = 1.57; 95% CI 1.07–2.30, top vs bottom category; processed meat HR = 1.27; 95% CI 1.06–1.54; data not shown). However, in the multivariable-adjusted model, there were no statistically significant associations of red meat, processed meat or fish consumption with total mortality for men and women (Table 2). In men, we observed an inverse association between white meat consumption and total mortality (P for trend = 0.02), but there was no such association among women. There were also no statistically significant associations between the intake of various meats or fish and death due to CVD or cancer, although there tended to be an inverse association between the consumption of fish and CVD for men and women combined (P for trend = 0.02) (Table 2).

HEI score

Table 3 shows baseline characteristics of the study participants based on the HEI categories. Participants that comply with the Food Guide Pyramid tend to eat less red and processed meat, but more white meat and fish. In general, subjects with a high HEI score tended to be older, non-Hispanic white, married, and more active, smoke less, have a lower BMI and waist circumference and eat more fruits and vegetables compared with participants with a low HEI. On the other hand, they tended more often to be hypertensive, have elevated cholesterol levels and a history of diabetes and take more dietary supplements (Table 3).

Total mortality was significantly lower with higher HEI score for all participants and men only (HR = 0.77, 95% CI 0.63–0.94; and HR = 0.7, 95% CI 0.52–0.96; Table 4). However, there was no statistically significant association between HEI score and total mortality among women. Moreover, there were no significant associations observed between HEI score and deaths due to CVD and cancer.

DISCUSSION

In this large cohort study, we observed that consumption of red meat, processed meat, white meat and fish was not significantly associated with increased or decreased risk of total mortality, cancer mortality and CVD mortality. However, there was an inverse association for men between the intake of white meat and total mortality. Furthermore, fish might have a favorable effect on CVD mortality.

Looking at the baseline characteristics the participants in this cohort may help explaining the null association between red and processed meat consumption and mortality we observed. On the one hand, red meat consumption was inversely associated with the use of dietary supplements, physical activity and fruit and fish consumption and positively associated with smoking and

Table 1. Baseline age-adjusted characteristics of participants according to quintiles of total red meat consumption

	Men (n = 8239) Consumption frequency (times/week)					Women (n = 9372) Consumption frequency (times/week)				
	0-6	7-14	15-29	30-44	45+	0-6	7-14	15-29	30-44	45+
Participants (%)	17.62	30.24	33.02	15.82	3.30	28.21	33.33	27.55	9.53	1.38
Age										
Mean	45.83	42.01	38.92	36.31	32.59	45.73	43.05	40.19	36.6	33.99
s.e.	0.48	0.56	0.48	0.65	1.06	0.61	0.54	0.66	0.84	2.12
Race/Ethnicity										
Non-hispanic white (%)	72.69	76.58	76.48	76.58	60.81	74.97	76.55	76.45	66.42	51.91
Non-hispanic black (%)	13.35	10.41	10.2	8.49	12.51	13.17	12.19	9.98	12.67	20.52
Mexican-American (%)	4.62	5.92	6.47	6.41	7.33	4.18	4.92	5.39	6.57	6.66
Other (%)	9.34	7.09	6.85	8.52	19.35	7.69	6.34	8.18	14.34	20.92
Hypertension, yes (%)	19.8	16.63	12.1	7.91	11.29	19.34	18.78	16.24	12.69	11.97
Diabetes, yes (%)	6.12	4.19	2.79	1.61	1.55	4.31	5.11	4.86	4.01	6.34
Hypercholesterolemia, yes (%)	24.76	18.59	13.08	11.49	12.7	23.33	17.29	15.03	11.5	15.75
Dietary supplement use, yes (%)	40.93	35.68	34.54	28.93	33.86	56	48.16	41.68	33.92	33.7
Smoking status										
Never (%)	41.98	42.42	38.9	35.28	32.93	58.85	57.72	52.29	54.56	63.24
Former (%)	36.65	31.39	24.15	21.75	23.18	22.7	18.73	16.11	10.95	7.58
Current, 1-19 cigarette/day (%)	9.22	9.65	13.42	13.75	15.54	9.71	11.12	14.77	12.03	10.05
Current, 20-39 cigarette/day (%)	1.64	3.08	6.74	6.49	10.95	2.43	2.59	3.59	5.51	2.42
Current, 40+ cigarette/day (%)	2.22	3.23	4.34	8.89	4.52	1.47	1.55	1.95	4.82	5.02
Missing information (%)	8.3	10.22	12.46	13.84	12.89	4.84	8.29	11.28	12.14	11.69
Moderate and vigorous physical activity per week										
0 (%)	9.15	9.84	9.4	11.78	9.19	15.1	16.98	18.79	21.82	21.34
0 to <2 (%)	15.89	21.11	23.05	22.83	26.67	20.13	25.41	28.59	27.27	24.23
2 to <4 (%)	15.05	16.29	16.12	14.66	16.71	15.76	17.08	17.39	16.75	17.27
4 to <6 (%)	8.61	10.54	9.83	9.48	4.16	7.58	8.05	7.77	6.18	3.83
6+ (%)	51.31	42.22	41.61	41.25	43.26	41.43	32.48	27.47	27.97	33.33
SES										
Poor (%)	10.72	10.19	11	10.11	8.03	11.66	12.45	14.62	20.87	24.31
Near poor (%)	18.47	16.52	17.54	21.12	24.78	17.95	19.69	21.18	24.23	32.41
Middle income (%)	32.36	37.67	39.82	40.11	52.26	31.88	35.82	38.32	34.22	25.51
Higher income (%)	32.47	28.22	26.15	22.49	10.38	31.58	24.85	18.91	13.44	11.89
Missing (%)	5.98	7.4	5.5	6.17	4.56	6.94	7.18	6.96	7.25	5.88
Marital status										
Married/living together (%)	64.66	66.87	68.54	62.5	54.88	49.87	61.11	65.95	62.13	47.61
Never married/widowed (%)	25.97	25.57	25.68	28.59	38.25	34.49	26.8	22.89	24.15	45.4
Divorced/separated (%)	9.37	7.49	5.71	8.87	6.87	15.43	12.01	10.99	13.68	6.99
Missing (%)	0	0.07	0.07	0.03	0	0.21	0.08	0.17	0.04	0

Table 1. (Continued)

	Men (n = 8239) Consumption frequency (times/week)					Women (n = 9372) Consumption frequency (times/week)				
	0–6	7–14	15–29	30–44	45 +	0–6	7–14	15–29	30–44	45 +
<i>BMI (kg/m²)</i>										
Mean	26.48	26.37	26.45	25.93	25.75	25.83	26.39	26.28	26.18	24.92
s.e.	0.18	0.2	0.15	0.33	0.68	0.22	0.15	0.32	0.34	0.86
<i>Waist circumference (cm)</i>										
Mean	94.76	94.2	94.22	92.71	90.81	86.54	88.23	88.15	87.9	83.42
s.e.	0.43	0.49	0.38	0.77	2.17	0.52	0.41	0.71	0.81	2.14
<i>Vegetables—times/month</i>										
Median	63.41	56.42	63.18	69.36	74.7	66.56	62.63	68.22	76.6	87.84
25th percentile	35.81	35.05	41.31	48.65	46.81	41.44	40.85	47.81	49.64	55.43
75th percentile	98.28	83.33	87.23	98.23	117.59	98.59	93.59	94.79	104.22	117.16
<i>Fruits—times/month</i>										
Median	43.37	35.56	31.84	30.74	37.06	49.23	41.63	37.29	33.83	42.41
25th percentile	20.33	15.14	13.74	9.84	12.29	23.92	18.74	16.19	13.5	16.7
75th percentile	68.88	60.44	52.91	52.88	68.28	75.14	69.24	62.99	63.43	94.11
<i>Processed meat—times/month</i>										
Median	1.26	3.67	8.3	8.63	10.29	0.53	3.13	3.89	5.64	8.72
25th percentile	0	1.51	3.12	3.37	3.57	0	0.68	1.61	2.17	3.17
75th percentile	3.88	8.82	14.02	18.97	27.44	3.22	7.39	9.74	13.06	26.21
<i>White meat—times/month</i>										
Median	7.82	7.32	8.01	3.98	8.23	8.28	8.27	8.25	4.95	7.57
25th percentile	3.02	3.22	3.29	3.14	3.46	3.26	3.44	3.43	3.16	3.52
75th percentile	12.5	11.01	10.25	9.36	12.85	12.61	12.35	12.29	11.32	15.43
<i>Fish—times/month</i>										
Median	3.14	2.89	2.49	2.3	3.48	2.92	3.03	2.75	1.81	1.68
25th percentile	1.03	0.77	0.72	0.54	1.24	0.61	0.89	0.68	0.33	0.61
75th percentile	8.32	3.96	3.97	3.86	7.52	5.73	4.48	3.94	3.64	3.75

Abbreviations: BMI, body mass index; SES, socioeconomic status.

Table 2. Multivariate analysis for meat and fish intake and total and cause-specific mortality

Consumption (times/month)	All, HR ^a (95% CI)	Men only, HR ^a (95% CI)	Women only, HR ^a (95% CI)	Interaction by sex (P-interaction)
<i>Total mortality</i>				
<i>Red meat</i>				
0–6	1 (reference)	1 (reference)	1 (reference)	0.77
7–14	1.01 (0.88–1.15)	0.94 (0.77–1.15)	1.09 (0.91–1.30)	
15–29	1.05 (0.87–1.28)	1.02 (0.79–1.31)	1.11 (0.89–1.38)	
30–44	0.93 (0.75–1.15)	1.02 (0.76–1.36)	0.71 (0.39–1.29)	
45 +	1.36 (0.92–2.00)	1.24 (0.76–2.02)	1.49 (0.76–2.94)	
P-trend	0.63	0.45	0.87	
<i>Processed meat</i>				
0	1 (reference)	1 (reference)	1 (reference)	0.50
1–6	0.91 (0.79–1.04)	0.95 (0.75–1.20)	0.90 (0.77–1.06)	
7–14	1.07 (0.93–1.23)	1.21 (0.93–1.58)	0.96 (0.79–1.16)	
15–29	0.99 (0.73–1.33)	1.00 (0.66–1.51)	1.11 (0.71–1.73)	
30 +	1.06 (0.85–1.33)	1.06 (0.75–1.50)	1.16 (0.86–1.55)	
P-trend	0.25	0.43	0.30	
<i>White meat</i>				
0	1 (reference)	1 (reference)	1 (reference)	0.16
0–3	0.88 (0.68–1.13)	0.83 (0.59–1.18)	1.08 (0.71–1.64)	
4–8	0.90 (0.71–1.13)	0.85 (0.60–1.2)	1.07 (0.71–1.60)	
9–12	0.77 (0.60–0.97)	0.68 (0.51–0.92)	0.98 (0.67–1.45)	
13 +	0.81 (0.64–1.03)	0.70 (0.48–1.01)	1.07 (0.71–1.63)	
P-trend	0.06	0.02	0.95	
<i>Fish</i>				
0	1 (reference)	1 (reference)	1 (reference)	0.23
0–2	1.02 (0.89–1.18)	1.01 (0.81–1.27)	1.02 (0.85–1.22)	
3–4	0.91 (0.8–1.04)	0.90 (0.74–1.11)	0.93 (0.76–1.14)	
5–8	0.86 (0.6–1.23)	0.82 (0.47–1.42)	0.86 (0.52–1.42)	
9 +	0.93 (0.78–1.11)	0.84 (0.67–1.04)	1.03 (0.79–1.35)	
P-trend	0.21	0.09	0.92	
<i>Cancer mortality</i>				
<i>Red meat</i>				
0–6	1 (reference)	1 (reference)	1 (reference)	0.67
7–14	0.93 (0.70–1.24)	0.95 (0.68–1.34)	0.91 (0.61–1.38)	
15–29	1.09 (0.75–1.57)	1.02 (0.67–1.56)	1.21 (0.69–2.09)	
30–44	0.79 (0.49–1.25)	0.89 (0.56–1.40)	0.62 (0.21–1.82)	
45 +	0.81 (0.36–1.84)	0.76 (0.26–2.23)	0.63 (0.09–4.69)	
P-trend	0.72	0.68	0.89	
<i>Processed meat</i>				
0	1 (reference)	1 (reference)	1 (reference)	0.48
1–6	0.76 (0.58–1.00)	1.23 (0.82–1.83)	0.60 (0.40–0.88)	
7–14	1.17 (0.92–1.49)	2.01 (1.37–2.96)	0.82 (0.57–1.18)	
15–29	1.31 (0.80–2.13)	1.96 (1.02–3.75)	1.33 (0.54–3.28)	
30 +	0.97 (0.63–1.49)	1.31 (0.84–2.05)	0.99 (0.45–2.17)	
P-trend	0.25	0.08	0.66	
<i>White meat</i>				
0	1 (reference)	1 (reference)	1 (reference)	0.13
0–3	1.21 (0.76–1.94)	1.54 (0.88–2.71)	1.37 (0.47–3.97)	
4–8	1.10 (0.72–1.68)	1.36 (0.85–2.19)	1.28 (0.47–3.52)	
9–12	0.84 (0.48–1.48)	0.78 (0.45–1.37)	1.20 (0.37–3.91)	
13 +	0.91 (0.55–1.48)	0.97 (0.62–1.50)	1.20 (0.37–3.93)	
P-trend	0.10	0.02	0.79	
<i>Fish</i>				
0	1 (reference)	1 (reference)	1 (reference)	0.68
0–2	1.08 (0.83–1.40)	1.41 (0.87–2.30)	0.89 (0.61–1.31)	
3–4	1.17 (0.88–1.57)	1.58 (1.05–2.37)	0.99 (0.60–1.61)	
5–8	0.84 (0.49–1.43)	0.99 (0.39–2.50)	0.72 (0.36–1.42)	
9 +	1.36 (0.96–1.92)	1.58 (0.89–2.81)	1.28 (0.80–2.05)	
P-trend	0.13	0.27	0.21	

Table 2. (Continued)

Consumption (times/month)	All, HR ^a (95% CI)	Men only, HR ^a (95% CI)	Women only, HR ^a (95% CI)	Interaction by sex (P-interaction)
CVD mortality				
<i>Red meat</i>				
0–6	1 (reference)	1 (reference)	1 (reference)	
7–14	1.12 (0.90–1.39)	0.95 (0.68–1.34)	1.26 (0.94–1.67)	
15–29	0.98 (0.69–1.38)	1.02 (0.67–1.56)	1.11 (0.80–1.55)	
30–44	0.94 (0.62–1.43)	0.89 (0.56–1.40)	1.06 (0.46–2.46)	
45 +	1.69 (0.84–3.43)	0.76 (0.26–2.23)	3.50 (1.35–9.05)	
P-trend	0.92	0.68	0.31	0.28
<i>Processed meat</i>				
0	1 (reference)	1 (reference)	1 (reference)	
1–6	0.86 (0.68–1.09)	0.79 (0.53–1.19)	0.92 (0.72–1.18)	
7–14	0.89 (0.66–1.20)	0.77 (0.46–1.27)	1.00 (0.72–1.38)	
15–29	0.76 (0.46–1.26)	0.47 (0.22–0.98)	1.36 (0.84–2.20)	
30 +	0.86 (0.59–1.26)	0.74 (0.41–1.33)	1.01 (0.67–1.52)	
P-trend	0.44	0.23	0.65	0.37
<i>White meat</i>				
0	1 (reference)	1 (reference)	1 (reference)	
0–3	0.95 (0.58–1.56)	0.70 (0.39–1.26)	1.26 (0.62–2.55)	
4–8	1.20 (0.77–1.88)	0.97 (0.57–1.66)	1.46 (0.74–2.88)	
9–12	1.01 (0.65–1.57)	0.95 (0.57–1.61)	1.09 (0.59–2.04)	
13 +	1.05 (0.65–1.71)	0.94 (0.51–1.73)	1.23 (0.66–2.29)	
P-trend	0.90	0.60	0.52	0.25
<i>Fish</i>				
0	1 (reference)	1 (reference)	1 (reference)	
0–2	1.04 (0.85–1.27)	1.15 (0.84–1.58)	0.89 (0.61–1.31)	
3–4	0.81 (0.66–1.00)	0.84 (0.59–1.20)	0.99 (0.60–1.61)	
5–8	0.81 (0.57–1.17)	0.72 (0.35–1.49)	0.72 (0.36–1.42)	
9 +	0.80 (0.63–1.01)	0.76 (0.55–1.07)	1.28 (0.80–2.05)	
P-trend	0.02	0.02	0.21	0.85

Abbreviations: BMI, body mass index; CI, confidence interval; CVD, cardiovascular disease; HR, hazard ratio; SES, socioeconomic status. ^aModels were adjusted for age, race, sex, cigarette smoking, alcohol consumption, physical activity, socioeconomic status, BMI, marital status, fruit and vegetables intake, history of hypertension, diabetes, hypercholesterolemia, use of aspirin and ibuprofen, use of mineral and vitamin supplements, family history of diabetes or hypercholesterolemia; hormone replacement therapy and oral contraceptive use (in women).

processed meat consumption, suggesting that the participants with moderate meat consumption had a beneficial profile of these risk factors for CVD and cancer. On the other hand, red meat consumption was inversely associated with age, blood pressure and BMI and was positively associated with vegetable consumption, suggesting that the participants with high red meat consumption had a beneficial profile of these risk factors for CVD and cancer. Adjusting for these factors in the multivariable Cox regression models, thus, attenuated the observed positive association between red meat consumption and overall mortality. However, in this respect, a limitation of this analysis has to be kept in mind: NHANES III only assesses food consumption with a simple food frequency questionnaire without the possibility of assessing portion sizes. Thus, we were not able to better categorize participants by using frequency and amount of food consumed per consumption event and also to calculate and adjust for energy intake as in previous studies to minimize confounding.^{11,12} Nevertheless, food frequency questionnaire is an appropriate tool for ranking subjects according to food and nutrient intake even if they do not assess portion sizes in addition to consumption frequency.²⁵ Unlike the cohorts in the analyses by Pan *et al.*¹² and Sinha *et al.*,¹¹ our cohort is not so strongly dominated by well-educated non-Hispanic white participants as NHANES III is representative for the US population. Additionally, measurement errors inherent in dietary assessments were inevitable, including misclassification of ham or cold cuts as

unprocessed meat and inaccurate assessment of meat content in mixed dishes.²⁵ Compared with analyses of the AARP¹¹ and the Health Professionals and Nurses Health cohorts,¹² the number of deaths due to cancer or CVDs is limited, and thus, we had sufficient power to determine a moderate association between red meat consumption and total mortality, but not moderate associations with cancer or CVD mortality.

Besides the very strong effects observed in the AARP¹¹ and the Health Professionals and Nurses Health cohorts,¹² some other recently published studies revealed only weak or even no associations between meat consumption and CVD mortality or cancer mortality.^{26–28} Moreover, depending of the cancer site there is more or less convincing evidence between meat consumption and an increased risk of cancer.⁵ Along with our weak results, we conclude that the strength of a possible association between meat consumption and total mortality still appears to be unclear and is likely very complex due to influences by various confounders. To support the evidence of a possible association between red/processed meat consumption and all-cause or cause-specific mortality, further research is warranted.

When looking at a dietary score instead of focusing on one specific group of foods, we observed a statistically significant inverse association between a good HEI score and total mortality, which was, however, only observed in men, but not in women. A possible stronger homogeneity in diet behavior among women, which would partially explain the difference between men and

Table 3. Baseline age-adjusted characteristics of participants according to tertiles of HEI

	Men (n = 8239)			Women (n = 9372)		
	HEI categories			HEI categories		
	1	2	3	1	2	3
Participants (%)	17.97	73.47	8.56	14.12	73.81	12.08
Age						
Mean	38.6	39.4	49.7	37.6	41.1	51.2
s.e.	0.54	0.41	1.08	0.61	0.43	0.88
Race/Ethnicity						
Non-hispanic white (%)	39.8	45.6	62.0	70.6	74.7	80.5
Non-hispanic black (%)	15.7	10.2	3.6	18.9	11.8	5.4
Mexican-American (%)	5.0	6.5	4.5	4.9	5.0	5.5
Other (%)	5.5	8.3	9.7	5.6	8.5	8.6
Hypertension, yes (%)	12.7	13.5	20.5	14.6	16.7	23.8
Diabetes, yes (%)	3.3	3.5	4.6	4.2	4.6	5.3
Hypercholesterolemia, yes (%)	12.1	15.6	32.2	11.3	17.4	28.3
Dietary supplement use, yes (%)	28.2	35.6	46.5	39.8	45.6	62.0
Smoking status						
Never (%)	29.7	42.3	43.8	45.6	56.7	67.2
Former (%)	23.8	26.8	46.1	12.9	18.2	23.1
Current, 1–19 cigarette/day (%)	16.2	10.9	5.6	20.0	11.3	5.9
Current, 20–39 cigarette/day (%)	6.5	4.9	0.7	5.5	3.0	0.6
Current, 40+ cigarette/day (%)	8.1	3.9	0.9	3.3	2.0	0.0
Missing information (%)	15.7	11.4	2.9	12.8	8.7	3.2
Moderate and vigorous physical activity per week						
0 (%)	11.4	9.5	5.8	19.1	17.4	11.5
0 to <2 (%)	24.4	21.3	14.5	30.4	25.3	18.2
2 to <4 (%)	16.3	16.1	15.1	14.9	17.5	16.8
4 to <6 (%)	10.0	9.4	9.2	8.1	7.7	7.2
6+ (%)	38.0	43.6	55.5	27.6	32.2	46.3
SES						
Poor (%)	16.4	9.3	6.8	17.3	13.9	7.6
Near poor (%)	19.0	18.4	13.3	23.5	20.3	16.0
Middle income (%)	39.4	39.6	29.9	35.6	35.6	34.6
Higher income (%)	19.5	26.6	43.5	17.2	23.7	33.6
Missing (%)	5.8	6.1	6.6	6.4	6.5	8.2
Marital status						
Married/living together (%)	62.4	65.4	79.2	58.3	59.5	63.9
Never married/widowed (%)	26.8	27.5	17.5	26.1	27.2	28.8
Divorced/separated (%)	10.7	7.1	3.4	15.5	13.2	7.0
Missing (%)	0.1	0.0	0.0	0.1	0.1	0.4
BMI (kg/m ²)						
Mean	26.6	26.3	25.9	26.1	26.3	25.8
s.e.	0.28	0.13	0.22	0.25	0.21	0.23
Waist circumference (cm)						
Mean	94.39	93.82	94.35	87.14	87.62	87.92
s.e.	0.61	0.32	0.65	0.66	0.45	0.67
Vegetables—times/month						
Median	52.7	63.2	81.2	57.5	65.5	62.3
25th percentile	35.08	40.03	53.68	36.52	42.38	89
75th percentile	81.03	89.35	111.2	83.1	94.5	126.71
Fruits—times/month						
Median	21.4	35.0	59.2	23.2	40.6	65.2
25th percentile	8.35	15.8	35.73	8.31	18.83	45.15
75th percentile	42.27	60.07	79.34	46.03	67.71	90.92

Table 3. (Continued)

	Men (n = 8239)			Women (n = 9372)		
	HEI categories			HEI categories		
	1	2	3	1	2	3
<i>Processed meat—times/month</i>						
Median	8.2	3.9	3.2	3.7	3.1	1.0
25th percentile	3.11	1.49	0	1.25	0.39	0
75th percentile	14.11	12.39	8.39	9.14	8.35	3.61
<i>White meat—times/month</i>						
Median	4.0	7.0	8.5	5.1	8.2	8.7
25th percentile	3.01	3.2	3.79	3.21	3.33	3.98
75th percentile	8.93	12.07	12.53	9.45	12.37	12.81
<i>Fish—times/month</i>						
Median	2.1	2.6	3.7	2.0	2.6	3.6
25th percentile	0.57	0.77	1.54	0.44	0.6	1.65
75th percentile	3.82	4.1	8.7	3.85	3.94	8.34
<i>Red meat—times/month</i>						
Median	16.4	14.9	10.4	13.0	11.7	7.9
25th percentile	9.34	8.39	4.2	7.51	5.17	3.56
75th percentile	25.74	24.4	17.55	20.97	17.98	13.71

Abbreviations: BMI, body mass index, HEI, healthy eating index; SES, socioeconomic status.

Table 4. Total and cause-specific mortality according to HEI score tertiles

	Poor (<51) HR ^a (95% CI)	Healthy eating index Needs improvement (51–80) HR ^a (95% CI)	Good (>80) HR ^a (95% CI)	P-trend	Interaction by sex (P-interaction)
<i>Total</i>					
All	1 (reference)	0.90 (0.75–1.08)	0.77 (0.63–0.94)	0.01	
Men	1 (reference)	0.85 (0.70–1.04)	0.70 (0.52–0.96)	0.02	
Women	1 (reference)	1.00 (0.73–1.36)	0.88 (0.65–1.20)	0.29	0.09
<i>Cancer</i>					
All	1 (reference)	0.82 (0.61–1.09)	0.75 (0.51–1.11)	0.14	
Men	1 (reference)	0.69 (0.05–0.95)	0.74 (0.46–1.17)	0.10	
Women	1 (reference)	1.09 (0.57–2.10)	0.94 (0.46–1.95)	0.82	0.38
<i>CVD</i>					
All	1 (reference)	0.87 (0.69–1.11)	0.85 (0.65–1.11)	0.26	
Men	1 (reference)	0.90 (0.67–1.21)	0.85 (0.50–1.43)	0.50	
Women	1 (reference)	0.85 (0.54–1.34)	0.86 (0.58–1.27)	0.51	0.31

Abbreviations: BMI, body mass index, CI, confidence interval; CVD, cardiovascular disease; HR, hazard ratio; HEI, healthy eating index; SES, socioeconomic status. ^aModels were adjusted for age, race, sex, cigarette smoking, alcohol consumption, physical activity, socioeconomic status, BMI, marital status, history of hypertension, diabetes, hypercholesterolemia, use of aspirin and ibuprofen, use of mineral and vitamin supplements, family history of diabetes or hypercholesterolemia, hormone replacement therapy and oral contraceptive use (in women).

women, could not be observed in the baseline characteristics. A recently published study by Rathod *et al.*¹⁸ reported a moderate inverse association between a good HEI score and total mortality and CVD mortality in an elderly cohort. However, no studies looking at the association between HEI and mortality in adults have been published so far,²⁹ but Akbaraly *et al.*³⁰ observed statistically significant inverse associations between all-cause and CVD mortality and a good alternative HEI score in the Whitehall study. However, in an attempt to improve the original HEI to better predict major chronic disease risk, alternative HEI is a modified dietary index and results cannot be fully assigned to the HEI.^{31,32}

For cancer and CVD mortality, we found no association with HEI. Although HEI considers nutrients that are associated with chronic

diseases, it is criticized that nutrients that have a protective role in the prevention are not taken into account in the construction of the HEI.³³ It has, for example, been argued that n-6 and n-3 fatty acids and dietary fiber should be included to better predict CVD and cancer, which lead to the development of the alternative HEI.^{34,35} The limited information of the HEI may partially explain the poor sensitivity of the HEI in assessing specific causes of death-like cancer and CVD. Our findings are consistent with recent findings that dietary indices are only weakly associated with clinical disease outcomes.^{14,15,36}

The HEI scores in our analysis are based on only one 24-h dietary recall instead of being based on food frequency questionnaire capturing habitual dietary behavior. However, when looking at food consumption based on the food frequency

questionnaire by HEI categories, we noted that those participants with a high HEI also had a more favorable diet, that is, high consumption of fruits and vegetables and rather low consumption of red and processed meat when compared with participants with low HEI. Interestingly, participants with a high score were more likely to have underlying diseases like hypertension and diabetes; nevertheless, they had a lower mortality rate than participants with a low HEI. It is likely that these participants have been advised by their treating physician or a dietician to change their dietary habits to improve their condition, for example, blood pressure or glucose levels. In general, higher HEI scores have been associated with higher energy and nutrient intakes, and also with higher concentrations of serum and red blood cell folate, serum vitamins C and E, and serum carotenoids and a lower mortality.^{18,37,38}

In conclusion, our data do not support the previously observed association between high red and processed meat consumption and increased mortality, which may be explained by the rather crude dietary questionnaire used in NHANES III in contrast to other cohorts. However, our results do support the importance of a healthy diet for overall mortality, although it cannot explain specific causes of death-like cancer and CVD.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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