

High Consumption of Red Meat Is Associated with Excess Mortality Among African-American Women

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ABSTRACT

Background: Red meat is a rich source of nutrients but is typically high in saturated fats. Carcinogenic chemicals can be formed during cooking and processing. Little is known about the relation of red meat consumption to mortality in African Americans (AAs), a group with excess mortality and high consumption of red meat relative to whites.

Objective: Our objective was to assess the association between red meat consumption and mortality in AA women.

Methods: The Black Women's Health Study (BWHS) is a prospective cohort study of AA women across the USA who completed health questionnaires at enrollment in 1995 (median age 38 y, median BMI 27.9 kg/m²) and every 2 y thereafter. The analyses included 56,314 women who completed a validated FFQ and were free of cardiovascular disease and cancer at baseline in 1995. Exposures were total red meat, processed red meat, and unprocessed red meat consumption. Outcomes were all-cause and cause-specific mortality. Cox proportional hazards models with control for age, socioeconomic status, lifestyle factors, medical history, and dietary factors were used to estimate HRs with 95% CIs.

Results: During 22 y of follow-up through to 2017, we identified 5054 deaths, which included 1354 cardiovascular deaths and 1801 cancer deaths. The HR for all-cause mortality was 1.47 (95% CI: 1.33, 1.62) for the highest quintile of total red meat consumption relative to the lowest. Each 1 serving/d increase in red meat consumption was associated with a 7% (95% CI: 5%, 9%) increased risk of all-cause mortality. Red meat consumption was also associated with increased cardiovascular mortality, but not with cancer mortality. Results were similar for the consumption of processed and unprocessed red meat.

Conclusions: Red meat consumption is associated with increased all-cause and cardiovascular mortality among AA women. *J Nutr* 2020;150:3249–3258.

Keywords: red meat, processed red meat, unprocessed red meat, mortality, African American, women

Introduction

Red meat is a widely consumed food group worldwide and consumption continues to rise, with the USA as the leading consumer (1–3). For Americans, red meat accounts for 58% of

total meat consumption and processed red meat accounts for 22% (1, 2). Red meat is a rich source of protein, B vitamins, zinc, and iron, but it is usually high in saturated fats. Furthermore, many carcinogenic chemicals, such as *N*-nitroso compounds, heterocyclic amines, and polycyclic aromatic hydrocarbons, can form during the meat processing and cooking process (4). The health implications of red meat consumption are of great public interest (5–8). Based on evidence predominantly from white populations (9–17), the WHO stated that red meat in general is “probably carcinogenic” to humans and processed red meat is “carcinogenic” (18). The 2015 committee for US dietary guidelines recommended that Americans cut down on red meat and processed red meat consumption (19), but some argue that lean beef can be part of a healthy diet (20).

In 2017, African-American (AA) women had a life expectancy of 78.5 y at birth, 2.7 y shorter than that of US white women (21). It is unknown whether red meat consumption contributes to the excess mortality among AAs. AAs consume

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Supplemental Tables 1–4 and Supplemental Figures 1 and 2 are available from the “Supplementary data” link in the online posting of the article and from the same link in the online table of contents at <https://academic.oup.com/jn/>.

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Abbreviations used: AA, African American; AHEI, Alternative Healthy Eating Index; BWHS, Black Women's Health Study; CVD, cardiovascular disease; MET, metabolic equivalent tasks.

more red meat and the trend has increased in recent years (22). AAs are also less likely to consume lean beef compared with whites (23), and they obtain more of their total fat intake from processed luncheon meats, bacon, and fried poultry (24). Even among AAs who consume a more plant-based dietary pattern, the consumption of red and processed red meat is still high and above the guideline recommended level (25, 26). Within the AA community, there is a wide range of culinary traditions, from the American South, the Caribbean, South America, and Africa. Soul food, which has deep historical and cultural connections with the AA community, may account, in part, for the greater preference for fried meat.

There has been little study of the relation of red meat consumption to all-cause and cause-specific mortality in an AA population. Zhong et al. (27) reported an association of processed meat and unprocessed red meat measured at baseline with increased all-cause mortality for non-Hispanic blacks. The study did not differentiate processed red meat from other types of processed meat, such as poultry, and did not examine cause-specific mortality. In the present study, with data from a large long-term cohort study, the Black Women's Health Study (BWHS), we assessed red meat consumption, processed and unprocessed, measured at 2 time points in relation to all-cause and cause-specific mortality in AA women.

Methods

Data described in this article, code book, and analytic code will not be made publicly available. Information on the procedure to obtain and access data from the BWHS is described at <http://www.bu.edu/bwhs> under the information for researchers.

Study population

The BWHS is a prospective cohort study of 59,000 AA women (age 21–69 y with a median age of 38 y at baseline), enrolled from across the continental USA in 1995 (28). Since 1995, participants have provided information on biennial mailed and web health questionnaires on demographic characteristics, socioeconomic factors, medical conditions, and lifestyle factors. Follow-up has been successful for 85% of potential person-years through 11 completed biennial rounds of follow-up. All but 5% of BWHS participants were born in the USA. The Boston University Medical Campus Institutional Review Board approved the study. Study participants gave informed consent.

Dietary information

In 1995 and 2001, participants completed modified versions of the National Cancer Institute Block FFQ, providing information on usual dietary intake in the past year (29). Questionnaire items on processed red meats included sausage, bacon, hot dogs, ham, bologna, salami, and other lunch meats. Questionnaire items on unprocessed red meats included hamburgers, and main dish or mixed dish of beef, beef stew, liver, and pork. For each food item, participants were asked, on average, how frequently they consumed the specific food item and the serving size. Responses ranged from “never or <1 per month” to “2 or more per day.” Serving sizes were “small,” “medium,” and “large” in the 1995 FFQ, with “super” added to the 2001 FFQ. Small was specified as about one-half of medium, large was about one and one-half times medium, and super was about twice the medium size. The medium serving sizes were 113 g (4 ounces) for unprocessed red meat, 28 g (2 slices) for bacon, 90 g (2 pieces) for hot dogs, 56 g (2 slices or 2 ounces) for sausage, salami, bologna, and other processed red meats. Total red meat consumption was calculated as the sum of processed and unprocessed red meat consumption.

In a validation study of 408 BWHS participants with 3 nonconsecutive 24-h recalls and 3-d food diaries over a 1-y period (29), the

deattenuated correlation coefficients (correlation after measurement error correction) (30, 31) were 0.45 for fat, 0.53 for saturated fat, and 0.58 for protein. Meat intake was not assessed separately.

Outcome assessment

The outcomes assessed were all-cause and cause-specific mortality. Deaths after baseline in 1995 through to 2017 were identified by searching the National Death Index for study participants who did not return the biennial questionnaire and were not previously known to be deceased. Reports of deaths were also obtained from next of kin, the Social Security Administration Death Master File, and the US Postal Service. Cause of death information (underlying and immediate cause) was obtained from the National Death Index Plus or a state-issued death certificate. Women were classified as having died from cancer if cancer was listed as the underlying cause of death based on the International Classification of Diseases codes (C00–C97 for cancer) and as having died from cardiovascular disease (CVD) if the underlying cause of death was codes I00–I09, I11, I13, I20–I51. The 5 leading causes of cancer death in the BWHS were breast cancer (26%), lung cancer (21%), pancreatic cancer (7.6%), colon cancer (6.7%), and ovarian cancer (4.6%).

Covariate assessment

Covariates were chosen a priori based on the literature and were adjusted as time varying. We included age (continuous), questionnaire cycle (continuous), BMI category (<23, 23–24.9, 25–29.9, 30–34.9, ≥35 kg/m²), education level (≤12, 13–15, 16, ≥17 y), geographic region (Northeast, South, Midwest, West), neighborhood socioeconomic status (quintiles) (32), physical activity level (<7.5, 7.5 to <15, 15 to <30, ≥30 h of metabolic equivalent tasks [MET] per week), cigarette smoking (cigarettes/d, continuous), family history of myocardial infarction (yes, no), family history of cancer (yes, no), history of diabetes (yes, no), history of hypertension (yes, no), history of hypercholesterolemia (yes, no), total energy intake (quintiles, kcal/d), and modified Alternative Healthy Eating Index (AHEI) without red meat (quintiles) (33, 34). All covariates were modeled as time varying, updating from report at baseline to report at the 2001 questionnaire cycle, which was the last cycle the FFQ was administered. Information on vigorous exercise and walking for exercise was obtained at baseline in 1995 and on 7 subsequent biennial questionnaires (35). We estimated energy expended per activity by multiplying the MET value by the number of hours per week spent for that activity and summing to estimate total energy expenditure in MET hours per week (MET-h/wk) from walking and vigorous activity. Hypertension was identified from biennial questionnaires as physician-diagnosed hypertension together with use of an antihypertensive medication or diuretic, or use of an antihypertensive alone. In a prior validation study, 99% of hypertension cases were confirmed by medical records (36, 37). Type 2 diabetes was self-report of physician-diagnosed diabetes at age 30 y or older; in a validation study, 95% of the women who reported diabetes were confirmed by their physicians to have type 2 diabetes (38).

Statistical analyses

The analytic sample consisted of 56,314 participants who provided information on their dietary intake and were free of CVD and cancer at baseline in 1995, with ≤9 blank responses on the 1995 FFQ and without implausible energy intake (<400 or >3800 kcal/d). For each study participant, follow-up was from baseline in 1995 until the date of death, loss to follow-up, or the end of study follow-up (31 Dec, 2017), whichever came first. We calculated the cumulative average of red meat consumption over the 2 cycles of dietary assessment to better reflect women's usual red meat intake and minimize within-person variation (39).

We used Cox proportional hazards models to examine associations of cumulative average red meat consumption with mortality. To assess dose-response relations, we used the restricted cubic spline method (40). We examined associations of total red meat, processed red meat, and unprocessed red meat intake with all-cause and cause-specific

TABLE 1 Age-standardized baseline characteristics in Black Women’s Health Study participants by quintile of total red meat consumption, processed red meat consumption, and unprocessed red meat consumption

	Total red meat				
	Q1	Q2	Q3	Q4	Q5
<i>N</i>	11,268	11,220	11,272	11,291	11,263
Total red meat, servings/d	0.04 ± 0.04	0.2 ± 0.1	0.4 ± 0.1	0.8 ± 0.1	2.1 ± 1.6
Age, y	39.5 ± 10.9	39.6 ± 10.7	38.9 ± 10.5	38.1 ± 10.3	36.6 ± 10.1
Neighborhood SES: highest quintile, %	22.9	21.7	18.9	15.7	12.0
Geographic region, %					
Northeast	33.5	29.0	26.2	24.8	23.4
South	25.7	29.5	31.6	33.2	33.4
Midwest	18.7	21.1	23.6	24.6	27.7
West	21.9	20.1	18.4	17.1	15.4
BMI, kg/m ²	26.3 ± 5.5	27.2 ± 6.0	27.9 ± 6.4	28.6 ± 6.9	29.6 ± 7.8
Pack years	3.2 ± 7.9	3.5 ± 8.2	3.9 ± 8.8	4.4 ± 9.5	5.3 ± 10.4
Physical activity, MET-h/wk	21.2 ± 18.9	18.1 ± 17.6	16.4 ± 16.9	15.2 ± 16.3	13.5 ± 15.6
Alcohol: current, %	23.7	26.7	28.3	30.5	34.9
Hypertension, %	19.1	21.9	23.5	24.7	27.4
Diabetes, %	2.6	3.5	4.1	4.7	6.8
Hyperlipidemia, %	20.8	21.8	20.3	20.4	20.7
Total caloric intake, kcal/d	1243 ± 747	1245 ± 722	1375 ± 738	1581 ± 857	2220 ± 1518
Diet quality, AHEI diet score without red meat component	33.5 ± 7.7	30.7 ± 6.9	29.0 ± 6.7	27.4 ± 6.7	26.0 ± 7.6
Vegetables, servings/d	2.6 ± 2.1	2.1 ± 1.6	2.2 ± 1.5	2.4 ± 1.7	3.5 ± 2.9
Fruits, servings/d	2.6 ± 2.1	2.2 ± 1.8	2.2 ± 1.8	2.3 ± 1.8	2.7 ± 2.2
Whole grains, servings/d	0.9 ± 0.8	0.8 ± 0.7	0.8 ± 0.7	0.9 ± 0.7	1.1 ± 1.0
Total fat, % kcal	29.8 ± 7.1	32.2 ± 6.4	34.1 ± 6.1	35.6 ± 5.8	38.2 ± 5.7
Fiber, g/d	13.9 ± 8.5	11.7 ± 7.3	12.1 ± 7.1	13.2 ± 7.2	16.7 ± 8.5
			Processed red meat		
	Q1	Q2	Q3	Q4	Q5
<i>n</i>	12,218	9978	11,742	11,119	11,257
Processed red meat, servings/d	0.01 ± 0.01	0.08 ± 0.03	0.2 ± 0.05	0.4 ± 0.09	1.2 ± 1.0
Age, y	38.9 ± 11.0	39.1 ± 10.6	38.9 ± 10.5	38.3 ± 10.2	37.4 ± 10.3
Neighborhood SES: highest quintile, %	22.7	20.9	18.8	16.6	12.0
Geographic region, %					
Northeast	31.7	27.5	27.3	25.7	23.9
South	25.6	29.5	30.5	34.1	34.1
Midwest	20.3	22.0	23.5	23.3	26.7
West	22.2	20.7	18.4	16.6	15.1
BMI, kg/m ²	26.5 ± 5.7	27.4 ± 6.1	27.9 ± 6.6	28.4 ± 6.9	29.3 ± 7.6
Pack years	3.2 ± 8.0	3.6 ± 8.6	3.9 ± 8.7	4.3 ± 9.3	5.1 ± 10.1
Physical activity, MET-h/wk	20.7 ± 18.8	17.5 ± 17.4	16.6 ± 16.9	15.5 ± 16.4	13.9 ± 15.9
Alcohol: current, %	24.1	27.1	28.3	30.0	34.9
Hypertension, %	20.3	22.3	23.1	24.0	26.9
Diabetes, %	2.8	3.6	3.8	4.9	6.3
Hyperlipidemia, %	20.6	21.7	21.0	20.3	20.8
Total caloric intake, kcal/d	1305 ± 804	1298 ± 768	1390 ± 785	1572 ± 867	2100 ± 1517
Diet quality, AHEI diet score without red meat component	32.9 ± 8.0	30.3 ± 7.2	28.9 ± 6.9	27.6 ± 6.8	26.6 ± 7.4
Vegetables, servings/d	2.7 ± 2.2	2.2 ± 1.7	2.2 ± 1.6	2.4 ± 1.6	3.2 ± 2.8
Fruits, servings/d	2.6 ± 2.1	2.2 ± 1.8	2.2 ± 1.8	2.3 ± 1.8	2.7 ± 2.2
Whole grains, servings/d	0.9 ± 0.8	0.8 ± 0.7	0.8 ± 0.7	0.9 ± 0.7	1.1 ± 0.9
Total fat, % kcal	30.3 ± 7.0	32.4 ± 6.6	33.9 ± 6.1	35.4 ± 5.9	38.0 ± 5.9
Fiber, g/d	14.3 ± 8.5	12.0 ± 7.5	12.2 ± 7.2	13.1 ± 7.2	15.9 ± 8.3
			Unprocessed red meat		
	Q1	Q2	Q3	Q4	Q5
<i>n</i>	11,513	10,962	11,592	10,913	11,334
Unprocessed red meat, servings/d	0.01 ± 0.02	0.1 ± 0.03	0.2 ± 0.04	0.3 ± 0.07	1.0 ± 0.8
Age, y	39.6 ± 10.8	39.8 ± 10.7	39.2 ± 10.6	37.8 ± 10.1	36.2 ± 9.9
Neighborhood SES: highest quintile, %	22.4	20.7	18.2	16.1	13.8
Geographic region, %					
Northeast	33.7	29.1	26.9	24.5	22.7
South	25.8	30.5	32.5	32.4	31.8

(Continued)

TABLE 1 (Continued)

	Total red meat				
	Q1	Q2	Q3	Q4	Q5
Midwest	18.8	20.6	23.2	25.3	27.9
West	21.3	19.5	17.1	17.5	17.3
BMI, kg/m ²	26.3 ± 5.6	27.3 ± 6.1	27.9 ± 6.5	28.5 ± 6.9	29.5 ± 7.6
Pack years	3.2 ± 8.1	3.4 ± 8.1	4.1 ± 9.1	4.5 ± 9.5	5.1 ± 10.2
Physical activity, MET-h/wk	20.8 ± 18.7	17.9 ± 17.6	16.5 ± 17.0	15.1 ± 16.1	13.9 ± 15.8
Alcohol: current, %	24.1	26.5	28.8	31.1	33.6
Hypertension, %	19.3	22.1	23.6	24.8	27.1
Diabetes, %	3.0	3.7	4.0	4.9	6.0
Hyperlipidemia, %	20.8	21.7	20.7	19.9	20.7
Total caloric intake, kcal/d	1274 ± 790	1256 ± 739	1392 ± 786	1590 ± 899	2158 ± 1478
Diet quality, AHEI diet score without red meat component	33.2 ± 7.7	30.5 ± 6.9	28.8 ± 6.8	27.7 ± 6.8	26.4 ± 7.8
Vegetables, servings/d	2.6 ± 2.1	2.1 ± 1.6	2.1 ± 1.6	2.5 ± 1.6	3.6 ± 2.9
Fruits, servings/d	2.6 ± 2.1	2.2 ± 1.8	2.2 ± 1.8	2.3 ± 1.8	2.7 ± 2.2
Whole grains, servings/d	0.9 ± 0.8	0.8 ± 0.7	0.8 ± 0.7	0.9 ± 0.7	1.1 ± 0.9
Total fat, % kcal	30.7 ± 7.2	32.5 ± 6.7	34.1 ± 6.4	35.5 ± 5.9	37.4 ± 5.7
Fiber, g/d	14.0 ± 8.5	11.8 ± 7.2	12.0 ± 7.0	13.4 ± 7.2	16.6 ± 8.5

AHEI, Alternative Healthy Eating Index; MET, metabolic equivalent of task; MET-h/wk, MET hours per week; Q: quintile; SES, socioeconomic status.

mortality. The proportional hazards assumption was tested by modeling multiplicative interaction terms between time and exposure variables. We repeated our analyses modeling red meat in grams/day using the Willett residual method (30). We also updated red meat exposure rather than assessing cumulative average. We repeated our analyses using the Fine-Gray method to account for competing risk (41). In subgroup analyses, we tested for potential effect modification by age, BMI, education, neighborhood socioeconomic status, smoking status, physical activity level, diet quality, and alcohol consumption using a likelihood ratio test.

Using a substitution modeling approach, we examined the change in the risk of death by replacing 1 serving of red meat per day with 1 serving of poultry, fish, whole grains, or vegetables. We used the differences in the β -coefficients for red meat and the substituted food to estimate the HR, and estimated the 95% CI using corresponding variances and covariances (42). We calculated population attributable risk fraction for the association between total red meat and all-cause mortality.

We grouped causes of cancer death into 6 categories (breast cancer [C50], lung cancer [C33–C34], pancreatic cancer [C25], colon cancer [C18–C21], ovarian cancer [C56], and other). The 5 leading causes of cancer death in the BWHS were breast cancer (26%), lung cancer (21%), pancreatic cancer (7.6%), colon cancer (6.7%), and ovarian cancer (4.6%). We examined associations of red meat with site-specific cancer mortality.

To examine potential biases, we performed several sensitivity analyses: 1) we modeled red meat consumption using baseline 1995 data only; 2) because undiagnosed major diseases could influence red meat intake, we conducted analyses excluding the first 2 y of follow-up; 3) alcohol consumption is highly associated with red meat consumption. In addition to adjusting alcohol as a component of diet quality score, we also included alcohol consumption as a covariate in the multivariable model and simultaneously adjusted for diet quality (AHEI derived without alcohol and red meat components). All analyses were performed using SAS software, version 9.4 (SAS Institute, Cary, North Carolina, USA).

Results

We followed 56,314 BWHS participants who reported red meat consumption and were free of chronic conditions at baseline. During 22 y of follow-up, we identified 5054 deaths, which included 1354 cardiovascular deaths, 1801 cancer deaths, and

1899 deaths from other causes. Participants were followed from 1995 until death or the end of follow-up (December 2017). Median follow-up was 17 y (IQR = 13–19 y).

Among the 56,314 women followed, 40,920 (73%) reported their red meat consumption again on the 2001 FFQ. Changes in red meat consumption were small. The mean intake of red meat intake was 0.76 (SD = 1.1) servings per day in 1995 and 0.80 (SD = 1.0) servings per day in 2001. The comparable values reported in 1995 and 2001 were 0.41 (SD = 0.67) servings per day and 0.46 (SD = 0.69) servings per day for processed red meat, and 0.35 (SD = 0.53) servings per day and 0.34 (SD = 0.53) servings per day for unprocessed red meat.

AA women who ate more red meat tended to be younger, have higher BMI, live in neighborhoods of lower socioeconomic status, live in the South or Midwest, smoke more, be less physically active, drink more alcohol, have high blood pressure or diabetes, consume a lower quality diet, and have higher total energy intake (Table 1). Similar characteristics were observed for unprocessed and processed red meat.

In multivariable-adjusted models, total red meat consumption was associated with higher all-cause mortality (Figure 1, Table 2). Elevated mortality was observed for both processed and unprocessed red meat (Supplemental Figures 1 and 2, Table 2). Compared with the lowest quintile of total red meat consumption, the HR for all-cause mortality in the highest quintile was 1.47 (95% CI: 1.33, 1.62, P -trend = 0.001); 9% (95% CI: 6%, 11%) of all-cause deaths were attributable to high total red meat consumption. The comparable HRs for cardiovascular and other cause mortality were 1.70 (95% CI: 1.40, 2.06) and 1.73 (95% CI: 1.46, 2.04), respectively. For cancer mortality, the HR for the highest quintile of total red meat consumption relative to the lowest was 1.09 (95% CI: 0.92, 1.29, P -trend = 0.72). Physical activity and smoking appeared to be the strongest confounders for the association with cancer mortality. Similarly, no associations were observed for processed and unprocessed red meat with cancer mortality (Figure 1, Table 2). No violations of the proportional hazard assumption were observed ($P = 0.32$).

For other mortality (Table 2), comparing the highest with lowest quintiles, HRs were 1.73 (95% CI: 1.46, 2.04) for total red meat, 1.53 (95% CI: 1.31, 1.79) for processed red meat, and

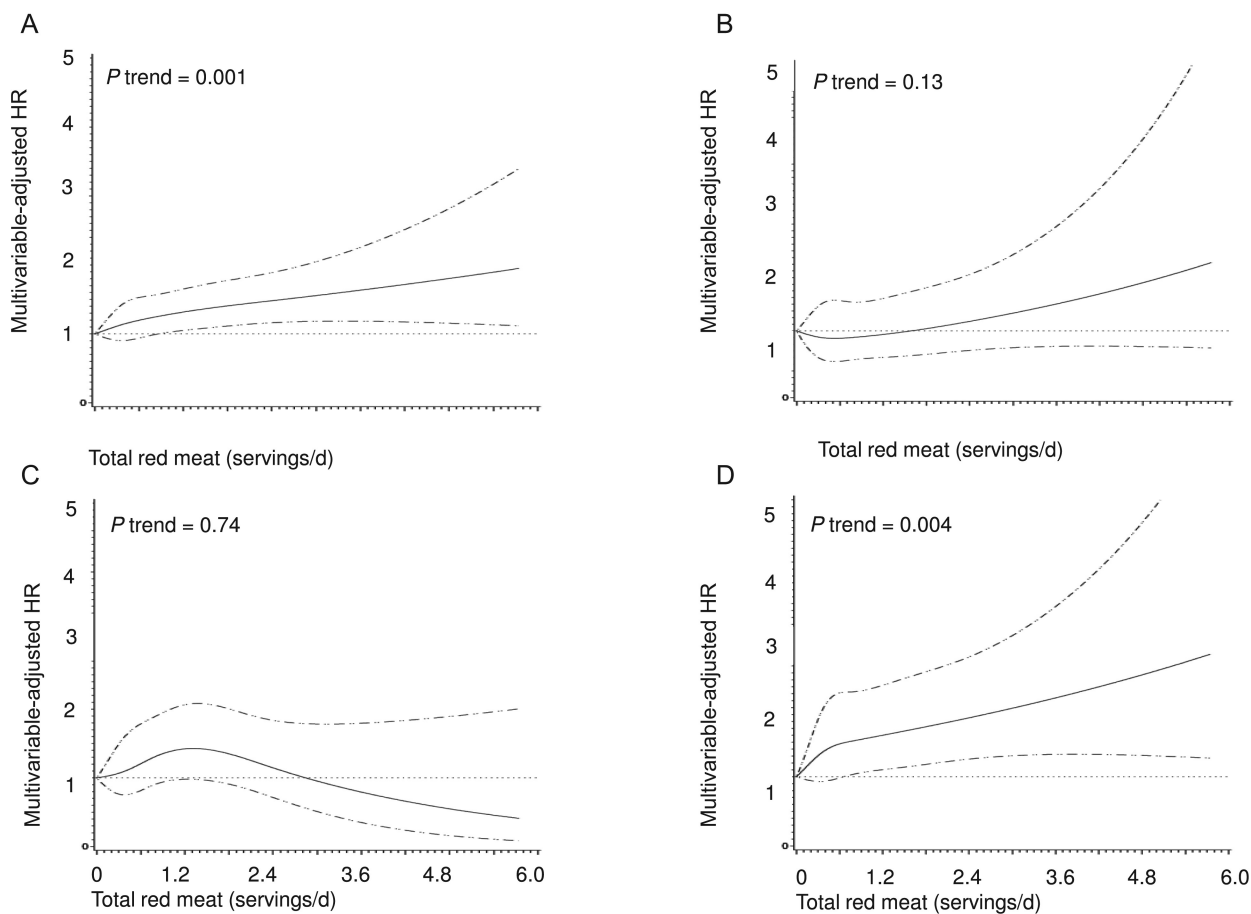


FIGURE 1 Splines of the associations of total red meat consumption with all-cause (A), cardiovascular disease (B), cancer (C), and other-cause (D) mortality among 56,314 African-American women. Multivariable adjusted model adjusted for age (continuous), questionnaire cycle (continuous), BMI (<23, 23–24.9, 25–29.9, 30–34.9, ≥ 35 kg/m²), educational level (≤ 12 , 13–15, 16, ≥ 17 y), geographic region (Northeast, South, Midwest, West), neighborhood SES (socioeconomic status) (quintiles), physical activity level (<7.5, 7.5 to <15, 15 to <30, ≥ 30 h of metabolic equivalent tasks per week), cigarette smoking (cigarettes/d, continuous), family history of myocardial infarction (yes, no), family history of cancer (yes, no), history of diabetes (yes, no), history of hypertension (yes, no), history of hypercholesterolemia (yes, no), total energy intake (quintiles, kcal/d), and modified 2010 Alternative Healthy Eating Index without red meat (quintiles, components include alcohol consumption).

1.59 (95% CI: 1.35, 1.87) for unprocessed red meat. Results remained the same after using the Fine-Gray method to account for competing risks (41).

In sensitivity analyses, we modeled red meat as a time-varying exposure rather than as a cumulative average, and we also used a residual method (Supplemental Tables 1 and 2); the results were similar to those in our main analysis shown in Table 2. For the substitution of 1 serving of red meat per day with poultry, there was an 18% reduction in mortality (HR = 0.82, 95% CI: 0.74, 0.91). Restriction to substitution with nonfried chicken yielded a similar finding (HR = 0.81, 95% CI: 0.73, 0.92). There was a 6% reduction in mortality (HR = 0.94, 95% CI: 0.90, 0.98) when vegetables were substituted for red meat, and an 11% reduction in mortality (HR = 0.89, 95% CI: 0.83, 0.95) when whole grains were substituted for red meat. Substituting 1 serving of red meat with fish was associated with a 9% reduction in mortality (HR = 0.91, 95% CI: 0.81, 1.01).

We examined the association of red meat with mortality among several subgroups (Table 3). The elevated mortality associated with high consumption of red meat was present in all subgroups, including “low risk” groups such as women with BMI <25 kg/m² and women aged <50 y. Null associations with cancer mortality were consistently observed for all subgroups.

Results were unchanged with additional control for more detailed categories of alcohol consumption instead of adjusting alcohol as a component of diet score. Results were unchanged in analyses that either used baseline diet data only or excluded the first 2 y of follow-up (Supplemental Table 3).

For site-specific cancer mortality, HRs for highest versus lowest quintiles of red meat consumption were 1.11 (95% CI: 0.74, 1.64, Supplemental Table 4) for lung cancer mortality ($n = 391$ deaths) and 0.77 (95% CI: 0.52, 1.14) for breast cancer mortality ($n = 407$ deaths). Small numbers prohibited investigation of other specific cancer sites.

Discussion

In 22 y of follow-up in a prospective cohort of 56,314 AA women, women who ate ~ 2 servings of total red meat per day had an estimated 42% increase in all-cause mortality relative to women who consumed almost no red meat. Mortality increased 6% per 1 serving/d increment of red meat intake. Associations were similar for processed and unprocessed red meat intake. Red meat intake was also associated with higher cardiovascular mortality, but the results provide little or no support for the

TABLE 2 Associations of total red meat, processed red meat, and unprocessed red meat consumption with all-cause and cause-specific mortality among 56,314 African-American women

	Total red meat				Processed red meat				Unprocessed red meat			
	n/person-y	IR	Model 1 ¹ HR (95% CI)	Model 2 ² HR (95% CI)	n/person-y	IR	Model 1 ¹ HR (95% CI)	Model 2 ² HR (95% CI)	n/person-y	IR	Model 1 ¹ HR (95% CI)	Model 2 ² HR (95% CI)
Quintiles of red meat intake in servings/d												
All-cause mortality												
Q1	826/239,359	3.45	Ref	Ref	835/240,680	3.47	Ref	Ref	815/234,848	3.47	Ref	Ref
Q2	955/239,864	3.98	1.15 (1.05,1.26)	1.05 (0.96,1.16)	895/233,738	3.83	1.09 (0.99,1.20)	1.02 (0.93,1.12)	1045/240,503	4.35	1.25 (1.14,1.37)	1.15 (1.05,1.27)
Q3	996/239,211	4.16	1.30 (1.18,1.42)	1.15 (1.04,1.26)	1004/244,039	4.11	1.24 (1.13,1.36)	1.11 (1.01,1.22)	1029/238,699	4.31	1.35 (1.23,1.48)	1.18 (1.07,1.29)
Q4	1057/238,664	4.42	1.50 (1.37,1.64)	1.25 (1.14,1.38)	1008/238,757	4.22	1.32 (1.21,1.45)	1.13 (1.02,1.24)	1031/239,151	4.31	1.50 (1.37,1.64)	1.25 (1.14,1.38)
Q5	1220/237,265	5.14	2.02 (1.85,2.20)	1.47 (1.33,1.62)	1299/236,143	5.50	1.89 (1.73,2.06)	1.40 (1.28,1.55)	1105/235,121	4.70	1.97 (1.80,2.16)	1.45 (1.32,1.61)
P-trend			<0.0001	0.001			<0.0001	<0.0001			<0.0001	<0.0001
per 1 serving/d				1.07 (1.05,1.09)				1.12 (1.08,1.15)				1.10 (1.05,1.15)
Cardiovascular mortality												
Q1	209/239,810	0.87	Ref	Ref	203/241,150	0.84	Ref	Ref	205/235,299	0.87	Ref	Ref
Q2	263/240,390	1.09	1.25 (1.04,1.50)	1.12 (0.93,1.34)	232/234,235	0.99	1.17 (0.96,1.41)	1.05 (0.87,1.28)	286/241,068	1.19	1.36 (1.14,1.63)	1.22 (1.02,1.47)
Q3	239/239,774	0.99	1.23 (1.02,1.48)	1.07 (0.88,1.29)	267/244,584	1.09	1.37 (1.14,1.64)	1.18 (0.98,1.42)	261/239,272	1.09	1.38 (1.15,1.65)	1.17 (0.97,1.41)
Q4	279/239,244	1.16	1.58 (1.32,1.89)	1.28 (1.06,1.54)	262/239,319	1.09	1.42 (1.18,1.70)	1.18 (0.98,1.43)	278/239,711	1.16	1.64 (1.37,1.96)	1.31 (1.08,1.58)
Q5	364/237,899	1.53	2.44 (2.06,2.90)	1.70 (1.40,2.06)	385/236,817	1.63	2.34 (1.97,2.78)	1.66 (1.38,2.00)	318/235,709	1.35	2.35 (1.97,2.81)	1.62 (1.33,1.97)
P-trend			<0.0001	0.001			<0.0001	<0.0001			<0.0001	0.04
per 1 serving/d				1.07 (1.03,1.11)				1.14 (1.07,1.21)				1.09 (1.00,1.18)
Cancer mortality												
Q1	350/239,708	1.46	Ref	Ref	348/241,041	1.44	Ref	Ref	333/235,198	1.42	Ref	Ref
Q2	351/240,319	1.46	1.00 (0.87,1.16)	0.96 (0.83,1.12)	347/234,155	1.48	1.01 (0.87,1.17)	0.99 (0.85,1.15)	410/240,980	1.70	1.20 (1.04,1.39)	1.16 (1.01,1.35)
Q3	397/239,663	1.65	1.22 (1.06,1.41)	1.13 (0.98,1.32)	375/244,499	1.53	1.11 (0.96,1.28)	1.05 (0.90,1.22)	358/239,209	1.50	1.15 (0.99,1.33)	1.07 (0.91,1.24)
Q4	362/239,182	1.51	1.21 (1.05,1.41)	1.10 (0.94,1.28)	355/239,250	1.48	1.12 (0.97,1.30)	1.02 (0.87,1.19)	366/239,643	1.53	1.29 (1.11,1.50)	1.18 (1.01,1.38)
Q5	341/237,917	1.43	1.33 (1.14,1.54)	1.09 (0.92,1.29)	374/236,827	1.58	1.30 (1.13,1.51)	1.09 (0.93,1.28)	325/235,702	1.38	1.41 (1.21,1.64)	1.20 (1.01,1.42)
P-trend			<0.0001	0.72			<0.0001	0.61			0.003	0.92
per 1 serving/d				1.01 (0.96,1.06)				1.02 (0.95,1.10)				1.00 (0.91,1.11)
Other mortality												
Q1	267/239,765	1.11	Ref	Ref	284/241,085	1.18	Ref	Ref	277/235,244	1.18	Ref	Ref
Q2	341/240,320	1.42	1.26 (1.08,1.48)	1.13 (0.96,1.33)	316/234,169	1.35	1.13 (0.97,1.33)	1.04 (0.88,1.22)	349/241,020	1.45	1.23 (1.05,1.43)	1.10 (0.94,1.29)
Q3	360/239,691	1.50	1.44 (1.23,1.69)	1.24 (1.05,1.45)	362/244,517	1.48	1.31 (1.12,1.53)	1.13 (0.97,1.32)	410/239,155	1.71	1.57 (1.35,1.83)	1.31 (1.12,1.53)
Q4	416/239,151	1.74	1.79 (1.53,2.09)	1.42 (1.21,1.67)	391/239,225	1.63	1.49 (1.28,1.74)	1.20 (1.02,1.41)	367/239,630	1.61	1.62 (1.39,1.90)	1.30 (1.10,1.52)
Q5	515/237,786	2.17	2.56 (2.20,2.97)	1.73 (1.46,2.04)	540/236,703	2.28	2.27 (1.97,2.62)	1.53 (1.31,1.79)	462/235,611	1.96	2.34 (2.01,2.72)	1.59 (1.35,1.87)
P-trend			<0.0001	<0.0001			<0.0001	<0.0001			<0.0001	<0.0001
per 1 serving/d				1.10 (1.07,1.13)				1.16 (1.10,1.22)				1.16 (1.09,1.23)

¹Model 1: adjusted for age (continuous), questionnaire cycle (continuous).

²Model 2: further adjusted for BMI (<23, 23–24.9, 25–29.9, 30–34.9, ≥35 kg/m²), educational level (≤12, 13–15, 16, ≥17 y), geographic region (Northeast, South, Midwest, West), neighborhood SES (socioeconomic status) (quintiles), physical activity level (<7.5, 7.5 to <15, 15 to <30, ≥30 h of metabolic equivalent tasks per week), cigarette smoking (cigarettes/d, continuous), family history of myocardial infarction (yes, no), family history of diabetes (yes, no), history of hypertension (yes, no), history of hypercholesterolemia (yes, no), total energy intake (quintiles, kcal/d), and modified 2010 Alternative Healthy Eating Index without red meat (quintiles, components include alcohol consumption). IR, incidence rate per 1000 person-years; n, case number; per 1 serving/d, 1 serving per day increment; Ref, reference; person-y, person-years; Q, quintiles.

TABLE 3 Associations of total red meat consumption with all-cause mortality in African-American women by BMI, age, neighborhood Socioeconomic Status (SES), education, smoking, physical activity, alcohol consumption, and AHEI score. SES, socioeconomic status

	All-cause mortality									P for interaction	
	N	Person-years	HR ¹ (95% CI)	n	Person-years	HR ¹ (95% CI)	n	Person-years	HR ¹ (95% CI)		
Quintiles of total red meat intake in servings/d											
			BMI <25			25 ≤ BMI <30			BMI ≥30		
Q1	242	97,353	Ref	279	79,082	Ref	268	55,040	Ref	0.72	
Q2	250	79,370	1.16 (0.97, 1.39)	300	80,505	1.00 (0.85, 1.18)	370	72,221	1.01 (0.87, 1.17)		
Q3	247	70,221	1.30 (1.08, 1.56)	308	80,055	1.06 (0.90, 1.25)	406	81,437	1.03 (0.89, 1.20)		
Q4	247	64,534	1.43 (1.18, 1.73)	317	74,111	1.22 (1.03, 1.45)	456	92,129	1.04 (0.90, 1.21)		
Q5	276	59,978	1.64 (1.34, 2.01)	298	65,242	1.35 (1.12, 1.62)	576	102,931	1.29 (1.11, 1.50)		
			Age <50			50 ≤ Age <65			Age ≥65		
Q1	128	126,040	Ref	291	85,391	Ref	407	27,928	Ref	0.61	
Q2	164	127,075	1.18 (0.94, 1.49)	369	85,218	1.15 (0.98, 1.34)	422	27,572	0.95 (0.83, 1.09)		
Q3	194	133,216	1.26 (1.01, 1.59)	357	81,933	1.08 (0.92, 1.26)	445	24,062	1.13 (0.98, 1.29)		
Q4	247	140,588	1.43 (1.14, 1.80)	380	77,256	1.11 (0.95, 1.31)	430	20,820	1.20 (1.04, 1.38)		
Q5	326	151,624	1.48 (1.17, 1.86)	523	70,203	1.46 (1.24, 1.72)	371	15,438	1.32 (1.13, 1.54)		
			Neighborhood SES Q1, Q2			Neighborhood SES Q3			Neighborhood SES Q4, Q5		
Q1	286	61,483	Ref	161	39,481	Ref	267	94,754	Ref	0.06	
Q2	385	69,631	1.09 (0.94, 1.27)	170	39,256	0.97 (0.77, 1.20)	287	88,813	1.05 (0.89, 1.24)		
Q3	406	74,586	1.18 (1.01, 1.38)	158	40,578	0.92 (0.73, 1.16)	298	82,196	1.15 (0.97, 1.37)		
Q4	500	80,454	1.39 (1.20, 1.62)	158	39,769	1.01 (0.80, 1.28)	247	74,993	1.12 (0.94, 1.35)		
Q5	628	95,263	1.60 (1.37, 1.87)	206	39,004	1.33 (1.05, 1.68)	195	57,656	1.23 (1.00, 1.51)		
			Education <16			Education 16			Education >16		
Q1	182	25,348	Ref	388	126,830	Ref	253	86,504	Ref	0.07	
Q2	249	35,874	1.02 (0.84, 1.24)	458	133,245	1.04 (0.91, 1.19)	235	70,167	1.06 (0.88, 1.26)		
Q3	274	37,872	1.17 (0.97, 1.42)	469	138,199	1.08 (0.94, 1.24)	238	62,332	1.16 (0.97, 1.40)		
Q4	297	42,249	1.22 (1.01, 1.48)	545	140,639	1.27 (1.11, 1.46)	209	55,011	1.17 (0.96, 1.42)		
Q5	431	55,334	1.52 (1.25, 1.84)	584	139,211	1.43 (1.24, 1.66)	184	41,864	1.33 (1.08, 1.65)		
			Smoking current			Smoking past			Smoking never		
Q1	131	19,753	Ref	271	51,999	Ref	422	167,222	Ref	0.48	
Q2	237	29,865	1.11 (0.89, 1.37)	268	48,028	1.00 (0.85, 1.19)	438	161,392	1.00 (0.87, 1.15)		
Q3	269	35,515	1.04 (0.84, 1.29)	270	45,294	1.13 (0.95, 1.34)	446	157,716	1.12 (0.97, 1.28)		
Q4	319	40,126	1.12 (0.90, 1.38)	299	43,003	1.37 (1.15, 1.63)	436	155,078	1.14 (0.99, 1.31)		
Q5	447	50,936	1.31 (1.06, 1.62)	269	39,896	1.43 (1.18, 1.73)	488	145,690	1.37 (1.18, 1.59)		
			Physical activity Q1, Q2			Physical activity Q3			Physical activity Q4, Q5		
Q1	424	77,648	Ref	125	35,626	Ref	275	125,854	Ref	0.70	
Q2	570	95,635	1.05 (0.93, 1.19)	122	37,032	1.03 (0.80, 1.33)	254	106,957	1.07 (0.90, 1.28)		
Q3	653	104,953	1.20 (1.06, 1.36)	116	37,206	0.95 (0.73, 1.24)	217	96,685	1.08 (0.90, 1.30)		
Q4	687	112,208	1.22 (1.08, 1.39)	133	36,902	1.22 (0.94, 1.58)	235	89,271	1.37 (1.14, 1.65)		
Q5	819	123,322	1.45 (1.27, 1.65)	134	33,817	1.33 (1.00, 1.76)	253	79,677	1.65 (1.36, 2.01)		
			Alcohol, never drinker			Alcohol, past drinker			Alcohol, current drinker		
Q1	227	55,888	Ref	169	33,817	Ref	415	147,407	Ref	0.13	
Q2	277	64,084	0.95 (0.79, 1.13)	196	33,748	1.08 (0.87, 1.33)	464	139,907	1.11 (0.97, 1.27)		
Q3	328	68,154	1.08 (0.91, 1.28)	189	32,548	1.13 (0.91, 1.40)	461	136,725	1.19 (1.04, 1.37)		
Q4	375	72,512	1.17 (0.98, 1.40)	232	32,873	1.48 (1.20, 1.83)	444	131,600	1.18 (1.03, 1.36)		
Q5	480	82,731	1.35 (1.13, 1.61)	226	33,426	1.57 (1.25, 1.97)	484	119,225	1.45 (1.25, 1.68)		
			AHEI Q1, Q2			AHEI Q3			AHEI Q4, Q5		
Q1	129	43,792	Ref	102	32,602	Ref	406	118,507	Ref	0.09	
Q2	197	62,488	1.04 (0.83, 1.30)	138	43,503	0.96 (0.74, 1.24)	392	95,462	1.08 (0.94, 1.24)		
Q3	261	80,848	1.21 (0.97, 1.50)	185	45,025	1.23 (0.96, 1.58)	367	77,357	1.17 (1.01, 1.35)		
Q4	345	100,024	1.26 (1.02, 1.57)	200	43,538	1.35 (1.05, 1.73)	310	59,745	1.24 (1.06, 1.46)		
Q5	452	113,391	1.43 (1.15, 1.78)	197	35,024	1.46 (1.11, 1.91)	298	47,903	1.61 (1.36, 1.92)		

¹Multivariable model adjusted for age (continuous), questionnaire cycle (continuous), BMI (<23, 23–24.9, 25–29.9, 30–34.9, ≥35 kg/m²), educational level (≤12, 13–15, 16, ≥17 y), geographic region (Northeast, South, Midwest, West), neighborhood SES (socioeconomic status) (quintiles), physical activity level (<7.5, 7.5 to <15, 15 to <30, ≥30 h of metabolic equivalent tasks per week), cigarette smoking (cigarettes/d, continuous), family history of myocardial infarction (yes, no), history of diabetes (yes, no), history of hypertension (yes, no), history of hypercholesterolemia (yes, no), total energy intake (quintiles, kcal/d), and modified 2010 Alternative Healthy Eating Index without red meat (quintiles, components include alcohol consumption).

AHEI, Alternative Healthy Eating Index; n, case numbers; Q: quintiles of total red meat intake in servings/d.

hypothesis that higher red meat consumption is associated with increased cancer mortality.

Currently, we are aware of only 1 other study that has reported on unprocessed red meat and mortality among AAs. Zhong et al. (27) reported a HR of 1.05 (95% CI: 1.02, 1.09) for each additional 2 servings of unprocessed red meat consumed per week with all-cause mortality for non-Hispanic blacks based on 1862 deaths. Diet was measured at baseline. The study did not differentiate processed red meat from other types of processed meat, such as poultry, and did not examine cause-specific mortality. Almost all of the existing evidence from follow-up studies of red meat and mortality is from whites, from the USA (10–12, 17, 27, 43, 44) and Europe (9, 14, 16, 45). There was 1 study of Asians (46). The NIH-AARP Diet and Health Study cohort contains AA participants (<4%) but race-specific results were not reported (10). It is possible that, compared with whites, AAs may have a different response to sodium intake (47, 48), and different iron (49), fatty acid (50–52), and lipid metabolisms (53–55). However, our findings on red meat and overall mortality are generally consistent with associations observed in studies of whites.

Our findings on red meat with CVD mortality are also consistent with the increased risk found for white Americans, Europeans, and Asian populations (56). A meta-analysis of red meat and CVD mortality reported a pooled HR of 1.19 (95% CI: 1.14, 1.25) (56). For CVD mortality, high concentrations of saturated fats and cholesterol from red meat partially explain the red meat and CVD mortality association (57, 58). Dietary iron, particularly heme iron, has been suggested to be associated with risk of CVD (59–62). Further, high sodium and nitrite concentrations in processed red meat have been associated with endothelial dysfunction, impaired insulin response, as well as risk of atherosclerosis (63, 64).

We found little evidence of an association of red meat intake with cancer mortality whereas studies of whites have found increased risk. For processed red meat in relation to cancer mortality in the present study, the HR was 1.02 (95% CI: 0.95, 1.10) for a 1 serving/d increase (Table 2). A meta-analysis of red meat intake and cancer mortality in whites reported a HR of 1.09 (1.06, 1.12) for US participants and 1.06 (1.02, 1.10) for European participants per 1 serving/d increase (56). For unprocessed red meat, the HR for per 1 serving/d increment was 1.00 (95% CI: 0.91, 1.11) in our cohort of AA women (Table 2), whereas it was 1.17 (1.09, 1.25) for US whites, 1.09 (0.81, 1.46) for Europeans, and 0.87 (0.79, 0.94) for Asians. It will be of interest to determine the association of red meat with cancer mortality in other studies of AAs.

Studies based on predominantly white populations reported a stronger association of processed red meat with mortality than for unprocessed meat with mortality (56). In our study, associations with mortality were similar for both processed and unprocessed meats. A difference between white and AA populations could be due to differences in types of processed and unprocessed red meat consumed or differences in cooking methods. For example, AAs are less likely to consume lean beef compared with whites (23) and more likely to use frying as the cooking method (24). In the BWHS, we did not have sufficient information to examine this possibility. In the study of Zhong et al. (27), HRs for all-cause mortality were similar for unprocessed red meat and processed meat, with 1.05 (95% CI: 1.02, 1.09) for unprocessed red meat and 1.03 (95% CI: 1.00, 1.05) for processed meat (per 2 servings/wk increment). However, this study did not differentiate processed red meat from processed poultry or other types of meat. Future studies of

AAs with detailed information on cooking methods and types of unprocessed and processed red meat are needed.

Our study is the largest providing evidence on red meat consumption with mortality for AA women, a population that has a high consumption of red meat and high mortality. BWHS participants were from several different geographic regions across the USA and live in neighborhoods of varying socioeconomic level. The strengths of the study were the large sample size, long-term follow-up, detailed information collected repeatedly on participants' lifestyle and medical conditions, and dietary information measured at 2 time points for both processed and unprocessed red meat.

Although we measured dietary intake at 2 time points, more measurements over time would have been desirable. Study participants typically underreport total caloric intake when responding to a FFQ, and that was likely the case in our study (30). We calculated a cumulative average to represent average red meat intake and to reduce random error. Misclassification due to measurement error could not be completely avoided. Although we conducted a dietary validation study, we did not examine correlation coefficients specifically for red meat. Frying and grilling are popular cooking methods among AAs and may contribute to higher contents of *N*-nitroso compounds, polycyclic aromatic hydrocarbons, and heterocyclic amines. We did not have detailed information on cooking methods and were not able to examine whether the associations differed by preparation or cooking procedures. Although we controlled numerous potential confounders, unmeasured confounding cannot be ruled out. We performed several sensitivity analyses to assess the influence of potential residual confounding and our results were consistent across different analytic strategies. We had no information on heme iron or nitrate concentration and therefore could not further evaluate the extent to which red meat and mortality association was mediated through these factors.

Red meat is a highly consumed food group worldwide, with Americans having the highest per capita intake. Investigation of the potential harms and benefits of red meat consumption among AAs is needed because of cultural differences in dietary intake and possible biological differences in terms of iron and lipid metabolisms. Given the disproportionately high mortality burden among AAs and the alarming progressive Westernization of diet across Africa, evidence from this investigation may have direct impact on AAs' perception of a healthy diet and everyday dietary choice. Results from our study provide direct evidence for AAs and could inform policymakers and community leaders both in the USA and Africa.

In conclusion, red meat consumption was associated with elevated all-cause and cardiovascular mortality among AA women. The lack of association observed with cancer mortality was unexpected; additional research in other AA populations is needed.

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The authors' contributions were as follows—study concept and design: SS, JRP, and LR; acquisition of data: LR and JRP; analysis and interpretation of data: SS, LR, and JRP; drafting of the manuscript: SS; critical revision of the manuscript for important intellectual content: SS, LR, and JRP; statistical analysis: SS; administrative, technical, or material support: LR and JRP; study supervision: LR and JRP; SS had primary responsibility for final content; and all authors: read and approved the final manuscript. SS had full access to all of the

data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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