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Meat consumption is associated with obesity and central obesity among US adults

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Abstract

Background—Meats are high in energy and fat content, and thus may be associated with higher risk of obesity. Many controversies remain regarding the association between meat consumption (MC) and obesity.

Objectives—The aim of this study was to analyze the associations between MC and obesity assessed using body mass index (BMI $\geq$ 30) and waist circumference ($\geq$ 102 cm in men and $\geq$ 88 cm in women) among US adults.

Methods—Nationally representative data collected in the 1999–2004 National Health and Nutrition Examination Survey (NHANES) were used. Linear and logistic regression analyses were conducted to test the associations between MC and adiposity measures controlling for potential confounders.

Results—Considerable differences existed in MC across sociodemographic groups among US adults. Those who consumed more meat had a much higher daily total energy intake, for example, those in the upper vs bottom quintiles consumed around 700 more kcal day⁻¹ ($P<0.05$). Regression models showed consistent positive associations between MC and BMI, waist circumference, obesity and central obesity, respectively. Using quintile 1 (low MC) as the reference, the association (odds ratio (OR) and 95% confidence interval (CI)) between total MC quintiles and obesity were 1.03 (0.88; 1.21; 2nd quintile), 1.17 (1.00; 1.38), 1.27 (1.08; 1.51) and 1.27 (1.08; 1.49; upper quintile), respectively; whereas that with central obesity was 1.13 (0.96–1.33), 1.31 (1.10; 1.54), 1.36 (1.17–1.60) and 1.33 (1.13; 1.55), respectively.

Conclusions—These US national cross-sectional data show positive associations between MC and risk for obesity and central obesity.

Keywords

dietary intake; meat consumption; central obesity; body mass index; waist circumference; NHANES

Introduction

Obesity increases the risks of a number of other chronic diseases, such as cardiovascular disease, hypertension, diabetes, dyslipidemia and certain types of cancer.¹ Obesity has become a global epidemic,^{1,2} and is becoming a public health crisis in the United States.^{3,4} National survey data show that the prevalence of obesity and overweight has doubled since the 1970s, with minority and low-socioeconomic status (SES) groups being disproportionately affected.

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^{4,5} Despite this rising trend, the primary causes for the epidemic and the disparities between population groups are still a matter of debate.

Although numerous studies have examined the influence of dietary patterns on risk of obesity, many controversies and uncertainties remain pertaining to the role of meat consumption (MC) on the risk for obesity or weight gain.^{6–9} For instance, a comprehensive review of 30 observational studies relating food intake patterns to anthropometric measures showed no consistent associations between body mass index (BMI) or obesity and food intake patterns.⁵ MC has been linked to higher intake of total fat, saturated fat and total calories, and a reduction in the consumption of vegetables,^{6,10} and higher risk of chronic disease, such as cardiovascular disease⁶ and type 2 diabetes.^{7,8} As a result, some researchers have advocated vegetarian diets for the prevention of diet-related chronic diseases including obesity.^{9–11}

On the other hand, others have advocated that a high-protein and low-carbohydrate diet promote weight loss and prevent obesity (for example, the Atkins diet).^{12,13} However, findings from controlled trials do not support that the Atkins diet is effective beyond 6 months; there is no clear evidence that Atkins style diets are better than other types of diet for helping people to lose weight; and their long-term effects on health and disease prevention are unknown.^{14,15}

In this study, we tested the associations between total MC or consumption of various types of meats and adiposity measures including BMI, waist circumference, obesity and central obesity on the basis of recent nationally representative survey data from a large number of US adults. Our findings will help shed light on the influence of people's food intake on weight status, and may help guide future intervention strategies.

Materials and methods

The National Health and Nutrition Examination Survey (NHANES) and study population

The NHANES include a series of cross-sectional surveys that provided nationally representative information on the nutrition and health status of the US civilian population. The National Center for Health Statistics (NCHS) conducted three waves of NHANES surveys (NHANES I, II and III) in 1971–1975, 1976–1980 and 1988–1994, respectively. Since 1999, NHANES has been a continuous survey. The data were recently made available for the first 6 years of the period 1999–2004. Since 1999, the NHANES has included all people of all ages from birth, although some earlier surveys excluded people aged 74 years or above. All of the NHANES surveys used a stratified, multistage probability cluster sampling design. The NHANES survey consists of an in-home interview for demographic and basic health information, and a health examination in a mobile examination center. Household interviews were conducted by trained staff. The mobile examination center personnel are physicians, medical and health technicians, and dietary and health interviewers. Detailed descriptions of the sample design, interview procedures and physical examinations conducted were published elsewhere.^{16,17}

NHANES data collected in 1999–2000, 2001–2002 and 2003–2004 from the US adults were merged and yielded a sample of 17 061 (8 091 men and 8 970 women) that had complete demographic data. Only 15 006 of them had complete dietary data (7 148 men and 7 858 women) and a smaller sample had both anthropometric and dietary data (14 616 for BMI and obesity, and 14 484 for waist circumference and central obesity). We further excluded pregnant and lactating women (~8% of the sample), which resulted in a final sample size of 13 602 for our key analyses of the associations between MC and adiposity measures.

Anthropometric measures and classification of obesity and central obesity

Measured weight, height and waist circumference were collected from each subject. This piece of information was used in our study to calculate BMI ($\text{=weight (kg)/height}^2 \text{ (m}^2\text{)}$) for each individual, and then was used to classify his/her weight status. BMI ≥ 25 was used to define overweight and BMI of ≥ 30 for obesity. To define central obesity, the waist circumference cut-points of 102cm (40") for men and 88cm (35") for women were used.¹⁸

Dietary intakes

In NHANES, 24 h dietary recalls were collected and used to estimate Americans' dietary intakes. In NHANES 1999–2002, only one 24 h recall was collected from each participant in the household interview. A second day of recall was collected from all participants in the 2003–2004 survey. Energy and nutrient intakes were calculated by the National Center for Health Statistics for NHANES on the basis of related food composition tables.¹⁹ We created the food groups for the NHANES data based on the major food groups, including meats, vegetables and fruits created by the US Department of Agriculture for the Continuing Survey of Food Intakes by Individuals (CSFII) data.²⁰ These food groups (measured in grams) were used in our analysis. When data on two 24-recalls were available, the averages of dietary intakes were used.

Meat groups—The different meats and meat products were grouped into the following: total meat (including all animal source food), red meat, poultry, seafood and other meat products. For example, red meat was the sum of beef, pork, lamb, veal and game. Poultry included chicken, turkey, duck and other poultry. Seafood included fish and shellfish. Other meat products included frankfurter and sausage, organ meats and food mixtures, mainly composed of meat, poultry and fish. For simplicity, we call the combined meat groups 'all meat' in contrast to all plant source food.

Vegetables and fruits—Fruit servings included whole fruit, including dried and mixed dishes, and 100% fruit juice. Vegetable servings were subdivided in the MyPyramid servings²¹ as dark leafy greens, deep yellow and orange, tomatoes, starchy vegetables and other vegetables. In our analysis, we used the total vegetables and fruits consumption (in grams) as a comparison for meat intake as well as a potential confounder when assessing the association between MC and total energy intake and risk of obesity. We also conducted a sensitivity analysis whereby the MyPyramid servings of fruits and vegetables were considered as confounders and were included as separate food groups in each model.

Grains—Similar to the consumption of vegetables and fruits, grain consumption was added to multivariate models as a potential confounding factor given its previously shown association with obesity and central obesity, and its contribution to energy intake. Our sensitivity analysis with servings instead of grams included whole grains and non-whole grains separately as potential confounders.

Main covariates and potential confounders

SES variables—The commonly used SES variables include education, income and occupational status, and each has its own strengths and limitations for studying the relationship between SES and health outcomes.²² In this study, we chose to use education and family income as the indicators of SES. Education was measured by years completed and then grouped into 0: 'below high school education', 1: 'high School' (12 years) and 2: 'above high school education'. The poverty/income ratio is the ratio of household income and the poverty line published by the Census Bureau for a certain family size in that calendar year. Specifically,

we used the poverty/income ratio categories of 0–100 (below the poverty line), 101–199 and $\geq 200\%$.

Physical activity—Physical activity was self-reported in terms of vigorous activity over the past 30 days that was dichotomized as 1 = yes and 0 = no, with missing or non-response values (accounting for around 5.4% of the sample) being included as a separate category. These physical activity variables were included as dummy variables in our models to control for physical activity as a potential confounder when we examined the associations between MC and obesity.

Other covariates—Other covariates considered as potentially confounding variables in our models included age (in years), gender and race/ethnicity. On the basis of the self-reported race and ethnicity, the participants were categorized as non-Hispanic whites, non-Hispanic blacks, Mexican American and the other. We also conducted a sensitivity analysis to assess the potential confounding effects of smoking status and alcohol consumption. Smoking was measured as never smoker, 'former smoker' and 'current smoker', whereas alcohol was measured as servings of alcoholic beverages on the basis of the 24-h recall data. Other MyPyramid servings of food groups included in the sensitivity analysis were as follows: added sugar, milk, cheese, yogurt, legumes, eggs, nuts, soy, discretionary fat (solid) and discretionary fat (oil).

Statistical analysis

To test the association between MC and BMI and waist circumference, we conducted linear and logistic regression analyses. In most cases, we studied MC as continuous variables, although we used sex-specific quintiles of MC also, when assessed their associations with average daily total energy intake and obesity and central obesity. These models controlled for age, sex, ethnicity, SES and physical activity, which were considered as potential confounders. All analyses were conducted using survey commands in STATA 9.0 to account for the complex sample design effects to achieve nationally representative estimates and unbiased statistical inference.²³

Results

Table 1 shows that on average, Americans had a high level of MC per capita (212 g day^{-1}). On the basis of the US Department of Agriculture's grouping system, over half (109.4 g , 52%) of MC were classified as 'other food product.' Red meat (40 g , 19% of all meat) was the most important specific type of meat consumed, followed by poultry (30 g , 14%) and seafood (14.2 g , 7%). Men had much a higher amount of MC than women, in total meat and subgroups of meats, especially in red meat ($53 \text{ vs } 28 \text{ g}$). Our unrepresented data also showed considerable age-, ethnic, and SES differences in the average intake levels.

Using linear regression models with daily total energy intake as the outcome variable and MC (or red meat) as the predictor, we examined the mean differences in people's total energy intake across quintiles of MC (or red meat), controlled for age, sex, ethnicity and SES. Clearly, those who consumed more meat had a much higher total energy intake (Table 2). In addition, using a similar approach, including food groups, as the predictors in the models, we estimated the contribution of MC to total energy intake and the differences across food groups by adding the same amount (100 g day^{-1}) of different food groups. We also compared the variance explained by these food groups, by computing partial R^2 values (See Appendix A). Overall, the four meat food groups, vegetables and fruits and grains explained 33% of the variance in total energy intake; the four meat food groups explained 11% of the variance, although if they were

collapsed into one group, it was 9%. Grains explained the largest proportion of the variance (16%); whereas vegetables and fruits explained the least (5%).

Tables 3–5 show the associations between MC and BMI, waist circumference and the risk of obesity and central obesity, controlled for demographic and SES factors as well as other selected food groups (mainly grains, vegetables and fruits). Table 3 also shows the proportion of the variance in the BMI and waist circumference of the US adults that could be explained by their consumption of the food groups included in the models, which were consistently very small. This was likely due to the fact that the 24-h recall data could not measure one's usual diet, and people's weight status was affected by a large number of factors.

Nevertheless, higher intakes of 'all meat' and 'other meat products' were associated with higher BMI and waist circumference, whereas intake of vegetables and fruits was inversely associated with BMI ($P < 0.05$). The positive association between 'all meat' and BMI/waist circumference remained significant even after controlling for vegetables and fruits and grain intakes. The OR and 95% CI presented in Table 4 show similar findings that higher consumption of 'all meat' and 'other meat products' was positively associated with the risk of obesity, whereas the intake of vegetables and fruits was inversely associated with the risk, with 'all meat,' retaining its significant association when vegetables and fruits were included.

We further conducted a sensitivity analysis (data not shown) whereby additional control was performed on smoking status, alcohol consumption and dietary intakes of add sugars, discretionary fat, servings of other food groups (namely dark green, deep yellow vegetables and potatoes, servings of fruits, servings of milk, cheese and yogurt, nuts, seeds, legumes and soy, serving of whole and non-whole grains, eggs, nuts, seeds and legumes). Our findings remained unaltered with a few exceptions, particularly the effects of red meat on waist circumference and central obesity, which was no longer significant and became borderline significant in the case of obesity.

Next, we used quintiles to group the subjects' 'all meat' and red MC into different levels, and assessed their association with obesity and central obesity (Table 5). Approximately, those in the top quintile seemed to be 27% more likely to be obese and 33% more likely to had central obesity. The association between all meat and red meat with obesity was similar, whereas it was weaker between red meat and central obesity than that with all meat (~19% vs 33%).

Discussion

On the basis of the recent nationally representative data, we found a positive association between the consumption of 'all meat' and 'other meat products' and BMI, waist circumference, obesity and central obesity. Those who had high MC (in the top quintile) were ~27% more likely to be obese, and 33% more likely to have central obesity compared to those with low MC (bottom quintile). These are likely due to their higher energy and fat contents. Indeed, those who had higher MC had higher energy intake. For example, on average, those whose MC being in the top quintile had ~700 kcal day⁻¹ higher energy intake than those in the bottom quintile. Even though the associations between MC and adiposity measures were relatively weak, findings based on these national data highlight the importance of examining the effect of MC on health including obesity.

During recent years, the Atkins diet, a well-known low-carbohydrate and high-meat diet, has drawn a great interest from many researchers and the general public for weight loss and for the prevention of obese and type 2 diabetes.¹² It is claimed that the restriction of carbohydrates could assist switch the body's metabolism from burning glucose to burning stored body fat.¹² A recent controlled randomized trial¹³ followed 311 premenopausal, non-diabetic middle aged women. The women lost more weight (mean 4.7 kg) on the Atkins diet than on three

higher carbohydrate diets (Lifestyle, Exercise, Attitudes, Relationships, and Nutrition (LEARN) 2.6 kg, Ornish 2.2 kg, and Zone 1.6 kg), without increasing cardiovascular risks. In contrast, an earlier randomized trial compared several diets, including the Atkins for weight loss and heart disease risk reduction, and found that Atkins had the least 1-year weight loss (mean (s.d.) weight loss was 2.1 (4.8) kg for Atkins, 3.2 (6.0) kg for Zone, 3.0 (4.9) kg for Weight Watchers, and 3.3 (7.3) kg for Ornish)¹⁵. An earlier review published before these two more recent controlled trials concluded that there is no proof that the Atkins diet is effective beyond 6 months; there is no clear evidence that Atkins style diets are better than any others for helping people to lose weight; and the long-term effects on health and disease prevention are unknown. They suggested a possible reason that participants lost weight because the diet was so monotonous, and hence they ate less, that is, people tended to eat a smaller amount of food when allowed fewer food choices in the meal.¹⁴

Meat consumption has been related to the increased risk for a variety of chronic diseases, whereas increased consumption of vegetables, fruits, cereals, nuts and legumes have been independently related with a lower risk for several chronic diseases, such as ischemic heart disease, diabetes, obesity and many cancers.^{10,11} Studies indicate that diets largely based on plant foods, including well-balanced vegetarian diets, which do not include meat, fish or fowl, offer a number of nutritional benefits, including lower levels of saturated fat, cholesterol and animal protein, as well as higher levels of carbohydrates, fiber, magnesium, potassium, folate and antioxidants. Compared with non-vegetarians, vegetarians have been reported to have lower BMI, blood pressure and blood cholesterol levels; lower rates of hypertension, type 2 diabetes and prostate and colon cancer, and reduced death rates from heart disease.^{9–11}

Our findings of a slightly stronger association between MC and central obesity than with obesity assessed using BMI are interesting, and might help explain the earlier findings of the association between MC and type 2 diabetes as waist circumference has been shown being a better predictor of type 2 diabetes and other obesity-related chronic disease than BMI.²⁴ Some recent large long-term cohort studies have reported a positive association between type 2 diabetes and the consumption of red meat and other processed meats.^{7,8} The Nurses' Health Study reported that the relative risk for diabetes for every 1-serving increase in intake increased by 26% for red meat, 38% for total processed meats.⁸ Data collected from 8 401 cohort members (ages 45–88 years) non-diabetic at baseline of the Adventist Mortality Study and Adventist Health Study (CA, USA) during a 17-year follow-up showed that those weekly consumers of all meats were 29% more likely to develop diabetes compared with those who did not consume meat.⁷

An important strength of this study is the use of nationally representative data to examine the associations. However, a major limitation is the cross-sectional data, which do not allow us to test causal relationships. It is possible that some obese/overweight individuals might have changed to consume more meat, for example, to follow the Atkins diet, and thus showed a positive association between MC and obesity. On the other hand, some overweight individuals might have reduced their MC because of concerns of the fat content of the meat. We cannot confirm which one is more common. The other limitation is the dietary data, that is, measurement error. Only 1–2 24-h dietary recalls were collected in NHANES 1999–2004. It has been proposed that at least four 24-h recalls are needed to measure individuals' usual food intake patterns.²⁵ Some earlier studies have also suggested an underreporting problem in national dietary surveys using 24-h recalls, such as earlier NHANES; for example, mean energy intake was found to be lower than energy requirements in 15% of all 24-h recalls.^{19–21} Generally, random or non-differential measurement error in exposures according to the outcome would bias the observed association toward the null, particularly when exposure and outcomes are binary and when the measurement error does not correlate with the truth.²⁶ However, dietary intake measures are likely to involve bias both related to true intake (for

example, high consumers may tend to underreport) and random variation, which could bias the results toward either directions, toward the null or overestimate.²⁷ Thus, further studies with better dietary measures and longitudinal data are needed.

In conclusion, our analysis on the basis of recent nationally representative data shows a consistent positive association between MC and adiposity measures among US adults. This along with the findings of adverse effect of MC on the risk of other chronic diseases revealed by other recent large cohort studies as well as the environmental impact of meat production argue against adopting a high-meat diet for long-term healthy weight management.

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Table 1
The meat consumption of US adults (g/day/person): NHANES 1999–2004

	Mean	s.e.	% of total meat
<i>Men and women</i>			
All meat	212.4	2.5	100
Red meat	39.9	0.8	19
Poultry	30.0	0.8	14
Sea food	14.2	0.7	7
Other meat products ^a	109.4	2.4	52
<i>Men</i>			
All meat	260.0	3.9	100
Red meat	52.9	1.2	20
Poultry	34.8	1.2	13
Sea food	16.5	1.0	6
Other meat products ^a	134.9	3.6	52
<i>Women</i>			
All meat	168.5	2.2	100
Red meat	28.0	0.9	17
Poultry	25.6	0.8	15
Sea food	12.1	0.7	7
Other meat products ^a	85.8	2.1	51

Abbreviation: NHANES: National Health and Nutrition Examination Survey.

^aOther meat products included frankfurter and sausage, organ meats and food mixtures, mainly composed of meat, poultry and fish.

Adjusted mean difference^a in total energy intake (kcal/day) by quintiles of meat and red meat consumption, stratified by gender: NHANES 1999–2004

Q1		Q2		Q3		Q4		Q5	
(ref)		β	s.e.	β	s.e.	β	s.e.	β	s.e.
Total meat	Q1: mean = 22 g (ref)	Q2: mean = 95.8 g		Q3: mean = 164 g		Q4: mean = 257 g		Q5: mean = 516 g	
Men	—	45.51	42.28	238.27**	48.53	443.25**	52.50	843.89**	55.09
Women	—	45.50	37.10	160.10**	27.26	306.54**	31.19	605.18**	35.06
Red meat	Q1: mean = 0 g	Q2: mean = 0 g		Q3: mean = 11 g		Q4: mean = 41 g		Q5: mean = 151 g	
Men	—	— ^b		26.90	78.97	15.50	41.70	412.90**	45.69
Women	—	— ^b		103.88	108.28	6.71	28.69	234.10**	29.71

Abbreviation: NHANES; National Health and Nutrition Examination Survey.

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 $P < 0.05$.

^a Adjusted mean differences (β) in total energy intake were estimated on the basis of linear regression models. Each model controlled for age, sex, ethnicity and socioeconomic status (SES).

^b The red meat consumption was 0 g.

Table 3
Association^a between meat consumption (100 g day⁻¹) and BMI and WC (cm): NHANES 1999–2004

	β	s.e.	P-value	R ^{2b}	Partial R ^{2c}
<i>BMI</i>					
<i>Model 1</i>	<i>n</i> = 13602				
All meat	0.11	0.03	<0.001**	0.0482	0.0024
<i>Model 2</i>	<i>n</i> = 13602			0.0490	0.0032
Red meat	0.22	0.10	0.026**		
Poultry	0.30	0.13	0.025**		
Sea food	0.21	0.12	0.104		
Other meat Products	0.11	0.05	0.026**		
<i>Model 3</i>	<i>n</i> = 13557			0.0523	0.0065
Red meat	0.23	0.08	0.011**		
Poultry	0.29	0.13	0.028**		
Sea food	0.25	0.13	0.060		
Other meat products	0.10	0.05	0.034**		
Fruits and vegetables	-0.07	0.02	<0.001**		
Grains	-0.01	0.03	0.734		
<i>Model 4</i>	<i>n</i> = 12613			0.0515	0.0057
All meat	0.12	0.03	0.001**		
Fruits and vegetables	-0.07	0.02	0.001**		
Grains	-0.01	0.03	0.650		
<i>WC*</i>					
<i>Model 1</i>	<i>n</i> = 12523			0.132	0.0028
All meat	0.21	0.07	0.007**		
<i>Model 2</i>	<i>n</i> = 13503			0.1324	0.0032
Red meat	0.44	0.24	0.070		
Poultry	0.48	0.31	0.129		
Sea food	0.37	0.30	0.230		
Other meat products	0.22	0.12	0.066		
<i>Model 3</i>	<i>n</i> = 12523			0.1416	0.0124
Red meat	0.44	0.22	0.048**		

	β	s.e.	P-value	R^{2b}	Partial R^{2c}
Poultry	0.43	0.30	0.162		
Sea food	0.44	0.29	0.140		
Other meat products	0.20	0.11	0.080		
Fruits and vegetables	-0.18	0.05	<0.001**		
Grains	-0.08	0.09	0.386		
Model 4	$n = 12523$			0.1413	0.0121
All meat	0.23	0.07	0.002**		
Fruits and vegetables	-0.17	0.05	0.001**		
Grains	-0.08	0.09	0.350		

Abbreviations: BMI, body mass index; NHANES, National Health and Nutrition Examination Survey, SES, socioeconomic status; WC, waist circumference.

**
 $P < 0.05$.

^aEach model controlled for age, sex, ethnicity, SES and physical activity.

^bThe value of the R^2 shows the proportion of the variance in BMI or that could be explained by all the variables included in the model.

^cThe value of the partial R^2 shows the proportion of the variance in WC that could be explained by the meat and/or VF or grain variables included in the model.

Table 4Association^a between meat consumption (per 100 g) and obesity (BMI $\geq$ 30) and central obesity: NHANES 1999–2004

	Obesity (BMI $\geq$ 30)		Central Obesity ^b	
	OR	95% CI	OR	95%CI
<i>Model 1</i>	<i>n</i> = 13602		<i>n</i> = 13503	
All meat	1.02	(1.00, 1.05)**	1.03	(1.00, 1.05)**
<i>Model 2</i>	<i>n</i> = 13602		<i>n</i> = 13503	
Red meat	1.06	(0.99, 1.13)	1.04	(0.97, 1.11)
Poultry	1.07	(0.97, 1.17)	1.07	(0.99, 1.16)
Sea food	1.02	(0.93, 1.12)	1.00	(0.93, 1.08)
Other meat products	1.03	(1.00, 1.06)**	1.04	(1.01, 1.08)**
<i>Model 3</i>	<i>n</i> = 12613		<i>n</i> = 12523	
Red meat	1.07	(1.00, 1.14)	1.04	(0.98, 1.11)
Poultry	1.05	(0.96, 1.16)	1.07	(0.98, 1.16)
Sea food	1.02	(0.92, 1.12)	1.00	(0.92, 1.09)
Other meat products	1.02	(0.99, 1.05)	1.04	(1.01, 1.07)**
Fruits and vegetables	0.97	(0.96, 0.99)**	0.98	(0.96, 0.99)**
Grains	0.99	(0.96, 1.01)	0.99	(0.96, 1.00)
<i>Model 4</i>	<i>n</i> = 12613		<i>n</i> = 12523	
All meat	1.02	(1.00, 1.05)**	1.03	(1.01, 1.05)**
Fruits and vegetables	0.98	(0.96, 0.99)**	0.97	(0.96, 0.99)**
Grains	0.99	(0.96, 1.01)	0.98	(0.96, 1.01)

Abbreviations: BMI, body mass index; CI, confidence interval; NHANES, National Health and Nutrition Examination Survey, OR, odds ratio; SES, socioeconomic status; WC, waist circumference.

**
P<0.05.

^aEach model is controlled for age, sex, ethnicity, SES and physical activity.

^bCentral obesity was defined as WC>102 cm for men and >88 cm for women.

Table 5

OR and 95% CI^a of obesity and central obesity by quintiles of meat and red meat consumption, stratified by gender: NHANES 1999–2004

	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
<i>Obesity (BMI ≥ 30)</i>										
<i>Total meat</i>	Q1: mean = 22 g (ref)	Q2: mean = 95.8 g	Q3: mean = 164 g	Q4: mean = 257 g	Q5: mean = 516 g					
All	1	1.03				1.17**	1.27**		1.27**	
Men	1	1.03				1.12	1.12		1.14	
Women	1	1				1.19	1.41**		1.36**	
<i>Red meat</i>	Q1: mean = 0 g	Q2: mean = 0 g	Q3: mean = 11 g	Q4: mean = 41 g	Q5: mean = 151 g					
All	1	— ^c				0.92	1.17**		1.20**	
Men	1	— ^c				0.94	1.30**		1.20	
Women	1	— ^c				1.13	1.05		1.18	
<i>Central obesity^b</i>										
<i>Total meat</i>	Q1: mean = 22 g (ref)	Q2: mean = 95.8 g	Q3: mean = 164 g	Q4: mean = 257 g	Q5: mean = 516 g					
All	1	1.13				1.31**	1.36**		1.33**	
Men	1	1.18				1.31**	1.34**		1.36**	
Women	1	1.06				1.27**	1.37**		1.26**	
<i>Red meat</i>	Q1: mean = 0 g	Q2: mean = 0 g	Q3: mean = 11 g	Q4: mean = 41 g	Q5: mean = 151 g					
All	1	— ^c				1.00	1.20**		1.19**	
Men	1	— ^c				0.96	1.22**		1.18	
Women	1	— ^c				1.89	1.18**		1.17	

Abbreviations: BMI, body mass index; CI, confidence interval; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio; SES, socioeconomic status; WC, waist circumference.

**
P < 0.05.

^a Each model is controlled for age, sex, ethnicity, SES and physical activity.

^b Central obesity was defined as WC > 102 cm for men and > 88 cm for women.

^cThe meat (or red meat) consumption was 0 g, and could not estimate OR.

Appendix A

Association^a between meat consumption (100 g/day) and total energy intake (kcal/day)

NHANES 1999–04 (N = 14980)					
	β	s.e.	P-value	R^{2b}	Partial R^{2c}
<i>Model 1</i>					
All meat	149.2	6.8	<0.001	0.29	0.09
<i>Model 2</i>					
Red meat	314.1	20.7	<0.001	0.32	0.11
Poultry	245.1	19.4	<0.001		
Sea food	199.8	18.9	<0.001		
Other meat products	143.6	6.9	<0.001		
<i>Model 3</i>				0.54	0.33
Red meat	337.2	15.2	<0.001		
Poultry	264.6	14.8	<0.001		
Sea food	202.0	17.0	<0.001		
Other meat products	166.7	7.3	<0.001		
Fruits and vegetables	52.0	2.8	<0.001		
Grains	177.1	4.4	<0.001		
<i>Model 4</i>					
Fruits and vegetables	54.7	2.9	<0.001	0.41	0.20
Grains	165.4	5.0	<0.001		
<i>Model 5</i>					
Fruits and vegetables	60.3	3.4	<0.004	0.26	0.05
<i>Model 6</i>					
Grains	166.1	4.3	<0.001	0.37	0.16

^aEach model is controlled for age, sex, ethnicity, education and poverty/income ratio.

^bThe value of the R^2 shows the proportion of the variance in total energy intake that could be explained by all the variables included in the model.

^cThe value of the partial R^2 shows the proportion of the variance in total energy intake that could be explained by the meat and/or vegetables and fruits or grain variables included in the model.