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Longitudinal Changes in BMI in Older Adults Are Associated with Meat Consumption Differentially, by Type of Meat Consumed[1–3]

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Abstract

Hypotheses regarding the role of meat consumption in body weight modulation are contradictory. Prospective studies on an association between meat consumption and BMI change are limited. We assessed the association between meat consumption and change in BMI over time in 3902 men and women aged 55–69 y from the Netherlands Cohort Study. Dietary intake was estimated at baseline using a FFQ. BMI was ascertained through baseline self-reported height (1986) and weight (1986, 1992, and 2000). Analyses were based on sex-specific categories of daily total fresh meat, red meat, beef, pork, minced meat, chicken, processed meat, and fish consumption at baseline. Linear mixed effect modeling adjusted for confounders was used to assess longitudinal associations. Significant cross-sectional differences in BMI between quintiles of total meat intake were observed (*P*-trend < 0.01; both sexes). No association between total fresh meat consumption and prospective BMI change was observed in men (BMI change highest vs. lowest quintile after 14 y: -0.06 kg/m^2; $P = 0.75$) and women (BMI change: 0.26 kg/m^2; $P = 0.20$). Men with the highest intake of beef experienced a significantly lower increase in BMI after 6 and 14 y than those with the lowest intake (BMI change after 14 y 0.60 kg/m^2). After 14 y, a significantly higher increase in BMI was associated with higher intakes of pork in women (BMI change highest vs. lowest quintile: 0.47 kg/m^2) and chicken in both sexes (BMI change highest vs. lowest category in both men and women: 0.36 kg/m^2). The results remained similar when stratifying on median baseline BMI, and age-stratified analyses yielded mixed results. Differential BMI change effects were observed for several subtypes of meat. However, total meat consumption, or factors directly related to total meat intake, was not strongly associated with weight change during the 14-y prospective follow-up in this elderly population. J. Nutr. 142: 340–349, 2012.

Introduction

Overweight and obesity have reached pandemic proportions, resulting in a growing global burden of obesity-related chronic disease (1,2). Hence, there is an increasing interest to identify modifiable factors in the diet that may be associated with maintaining a healthy body weight. In this respect, several plausible hypotheses underlie a potential role for meat consumption in the development of adiposity.

Cross-sectional research has shown considerable lower obesity rates among vegetarians compared to meat-eaters in Western populations (3–7). However, whether these differences in body weight can be explained by abstaining from consuming meat, the higher intake of beneficial dietary components such as fruit and vegetables, the overall lower energy intake, or the more favorable nondietary lifestyle factors of vegetarians has been debated. Nonetheless, cross-sectional studies examining the effect of meat consumption in particular on body weight have yielded ambiguous results (8–11) but are above all limited by their inability to distinguish between cause and effect.

Until now, two longitudinal studies investigated the possible role of vegetarianism in preventing weight gain. Rosell et al. (12) observed only small differences in weight gain between meat-eating and vegetarian men over a 5-y period, whereas a smaller study in Seventh-day Adventists (13) showed nonsignificant and mixed results. The few studies that prospectively examined the role of dietary meat consumption for weight maintenance yielded mixed results (14–21) and mostly reported only on the

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[3] Supplemental Figure 1 is available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at jn.nutrition.org.
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effects of total meat intake and not on different sources and types of meat products.

In contrast, high-protein diets have also been advocated for weight reduction and body weight regulation. Meat products are generally a rich source of high-quality proteins, which may increase satiety and upregulate thermogenesis (22). Although well-designed, long-term studies are lacking, high-protein diets have shown to positively affect weight maintenance in the short term (23). In addition, studies on the weight-reducing potential of the specific high-protein, low-carbohydrate Atkins diet (24), containing ad libitum amounts of meat, have been inconsistent (25–28).

The Netherlands Cohort Study on Diet and Cancer (NLCS) acquired data from up to 3 consecutive weight measurements over a period of 14 y for 5000 elderly individuals who were randomly selected from the total cohort. This study provides the unique opportunity to examine the association between the dietary intake of fresh meat, processed meat, poultry, and fish and subsequent BMI change over time in the general elderly population.

Methods and Procedures

Participants and study design. The NLCS was conceived in September 1986 with the enrollment of 120,852 individuals in The Netherlands and the purpose to investigate the associations between diet and the development of cancer. The cohort comprised 58,279 men and 62,573 women aged 55–69 y at baseline who completed a self-administered questionnaire on dietary habits, lifestyle, medical history, and demographic information. Municipal registries throughout The Netherlands were used to constitute an effective sampling frame of the population. Full details of the study design have been described elsewhere (29).

The NLCS is a case-cohort design with a subcohort of 5000 individuals randomly selected from the larger cohort on recruitment into the study. These individuals have been followed-up biennially from baseline in 1986 for migration and vital status to estimate person time at risk. Follow-up of the subcohort has also allowed for the additional accumulation of prospective data regarding a number of factors related to body weight and weight change. This subcohort was used for the present study.

For the current analyses, individuals who returned incomplete baseline dietary questionnaires, individuals with missing values for height or weight at baseline, and all prevalent cancer cases other than skin cancer at baseline were excluded. This resulted in an initial study population of 4280 individuals. Follow-up measurements regarding BMI were recorded in the years 1992 and 2000 and data were available for 3787 and 2091 individuals, respectively, at these time points. The NLCS has been approved by the institutional review boards of the CIVO-TNO Research Institute (Zeist, The Netherlands) and Maastricht University (Maastricht, The Netherlands). The Institutional Review Board of Maastricht University approved the analyses reported herein.

Dietary assessment. Habitual meat intake at baseline was assessed using a self-administered, semiquantitative FFQ consisting of 150 food items estimating the average frequency of foods and beverages consumed over the previous 12 mo. The questionnaire contained 14 items on the consumption of meat with the hot meal (mainly fresh meat, including chicken), five items on the consumption of meat products used as sandwich fillings, and three items on fish consumption. This dietary assessment was part of a larger questionnaire that included questions regarding several lifestyle factors.

Fresh meat consisted of beef, pork, minced meat (including beef and pork), chicken, liver, and other meat (e.g., horsemeat, lamb). Fresh red meat consisted of the fresh meat items minus the chicken item. Coding of fresh meat items was based on raw weight to take into account the amount of fat originally present in the meat but eventually ending up in the gravy, which is usually consumed as well. Processed meat was defined as meat items that had undergone some form of preservation (mostly treatment with nitrate salt, some types smoked or fermented). The meat intake in each participant's diet was calculated from the FFQ dietary data by summing the multiplied frequencies and serving sizes of the meat items.

Ascertainment of BMI. Full details of the ascertainment of BMI were previously described in more detail by Hughes et al. (30). In short, height (cm) was reported on the baseline questionnaire. Body weight (kg) was reported on questionnaires at baseline in 1986, 1992, and 2000. At all 3 time points, the weight measurement was self-reported. BMI (kg/m^2) was calculated for each time point by using the recorded weight at each time point divided by height squared at baseline. Moreover, the baseline questionnaire included the open-end question, "What was your weight at age 20 y (kg)?" and a corresponding BMI was calculated using the recorded weight at age 20 y divided by height squared at baseline (age 55–69 y). An overview of the study design is presented in **Supplemental Figure 1**.

Statistical analyses. Data were analyzed using Stata (Intercooled STATA, version 11; Stata-Corp). All analyses were conducted separately for different types of meat intake and were stratified by sex. Self-reported vegetarians (n = 132) were excluded from analyses. Total fresh meat consumption was quantified using 2 different variables: quintiles of intake (in g/d) and weekly frequency of meat intake (0–3, 4–5, and 6–7 d/wk). Sex-specific intakes of total fresh meat, weekly meat consumption frequency, fresh red meat, beef, pork, minced meat, chicken, processed meat, and fish were assessed. Mean total meat and individual meat product intake as well as other population characteristics were analyzed using data from the baseline questionnaire. Pearson correlation was applied to determine the association between continuous baseline characteristics and total fresh meat consumption. Cross-sectional differences in baseline BMI values per quintile of total fresh meat consumption were examined by using a linear regression model adjusted for confounding variables selected for the longitudinal analyses as described below.

Linear mixed effect (LME) modeling was applied to assess the change in BMI over time and the longitudinal relation between meat consumption intake at baseline and BMI at baseline (1986), in 1992, and in 2000. The mixed model consists of 2 parts: fixed effects and random effects. Fixed effects describe population slopes for a set of considered covariates, which include exposures and confounders. Random effects describe individual variability in outcome and changes over time. We considered a model with individual random slopes for time. The model allowed us to examine the influence of covariates on the change in BMI over time (31). This model also accounts for the correlation between repeated measures and accounts for missing values at different time points (32).

For the LME model, a categorical time variable was created by using the values 0, 6, and 14 reflecting the time points (in years) of the BMI measurement from baseline. Two dummy variables indicating the three time points and four meat intake dummy variables (reflecting quintiles or five categories of intake) were entered into the model. In case of chicken and fish consumption, 3 dummy variables were entered, and for reported weekly frequency of meat intake, two dummies were created (reflecting the four or three categories of intake, respectively). Furthermore, interactions of the time dummies with the meat intake dummies (eight, six, or four interaction terms, respectively) were included. A random slope for time at the individual level was obtained by using time as a continuous variable. Longitudinal information was derived by considering the regression coefficients of the time dummies and of the meat-time interaction terms. The coefficients of the time dummies reflect the change in BMI over time (6 and 14 y, respectively) in the lowest quintile/category. The coefficient of an interaction term gives the difference between the change in BMI in a quintile/category after 6 and 14 y and the change in BMI in the lowest quintile/category of meat intake as the reference category. All models were examined for evidence of an overall trend by statistically testing whether any of the time × quintile interaction terms were equal to zero. This provided an overall assessment as to whether the increase in BMI over time differed between the quintiles/categories of intake; if significant, the direction of this trend should be quantified based on the individual coefficients of interaction.

TABLE 1 Baseline characteristics of the subcohort in the Netherlands Cohort Study and their association with the total intake of fresh meat[1]

Characteristics	Men (n = 1991)	r^2	P value[3]	Women (n = 1911)	r^2	P value[3]
Demographics						
Age, *y*	61.3 ± 4.2	−0.06	<0.05	61.3 ± 4.3	−0.04	0.12
Anthropometrics						
Height, *cm*	176.6 ± 6.6	0.06	<0.05	165.2 ± 6.1	−0.01	0.98
Weight, *kg*	77.7 ± 9.4	0.15	<0.05	68.2 ± 10.0	0.18	<0.05
BMI, *kg/m²*	24.9 ± 2.5	0.14	<0.05	25.0 ± 3.5	0.19	<0.05
Dietary factors						
Total energy intake, *kcal/d*	2170 ± 503	0.22	<0.05	1690 ± 391	0.18	<0.05
Types of fresh meat, processed meat and fish, *g/d*						
Total fresh meat[4]	106 ± 42.6			92.8 ± 39.3		
Fresh read meat[5]	93.2 ± 41.0	0.93	<0.05	80.0 ± 37.8	0.92	<0.05
Beef	27.6 ± 23.9	0.45	<0.05	24.3 ± 2.16	0.41	<0.05
Pork	40.9 ± 30.1	0.62	<0.05	35.0 ± 28.1	0.65	<0.05
Minced meat[6]	19.9 ± 17.7	0.44	<0.05	16.7 ± 15.0	0.40	<0.05
Chicken	13.5 ± 14.5	0.30	<0.05	13.6 ± 15.9	0.31	<0.05
Processed meat	16.0 ± 17.0	0.13	<0.05	10.4 ± 11.6	0.17	<0.05
Fish	14.6 ± 16.8	0.01	0.72	11.7 ± 13.9	0.01	0.76
Lifestyle behaviors						
Cigarette smoking status, *%*						
Never	12.9			56.5		
Former	51.8			21.8		
Current	35.4			21.8		
Alcohol Intake, *g/d*	15.1 ± 17.1			6.0 ± 9.7		
Physical activity, *%*						
<30 min/d	17.5			22.8		
30–60 min/d	31.1			31.2		
60–90 min/d	19.4			23.4		
>90 min/d	32.0			22.6		

[1] Values are mean ± SD, percent, or *r*.
[2] Pairwise correlation coefficient correlated with total fresh meat intake, including all types of meat (except processed meat) and poultry.
[3] *P* values for pairwise correlation coefficients.
[4] Including all types of meat (except processed meat) and poultry.
[5] Including beef, pork, minced meat, liver, and other meat.
[6] Including beef and pork.

In addition to an unadjusted and age-adjusted model, we created an LME model adjusted for age plus confounding variables. These confounding variables were identified as being associated with both BMI and meat intake from the previous literature or were variables that, when entered in our model, resulted in a >10% change in the regression coefficients. These include age (years), total energy intake (kcal), nonoccupational physical activity (min/d), smoking status (never, ex, and current smoker), education (low, medium, high), alcohol intake

TABLE 2 Baseline BMI by quintile of total fresh meat consumption in the subcohort of the Netherlands Cohort Study[1]

Quintile of total fresh meat consumption[3]	Men (n = 1991)[2]		Women (n = 1911)[2]	
		BMI		BMI
	n	*kg/m²*	n	*kg/m²*
1	395	24.5 (24.3–24.7)	389	24.1 (23.8–24.4)
2	401	24.7 (24.6–24.9)	371	24.7 (24.5–24.8)
3	406	24.9 (24.8–25.0)	387	25.0 (24.8–25.1)
4	394	25.0 (24.9–25.2)	392	25.3 (25.1–25.4)
5	395	25.4 (25.2–25.6)	372	26.0 (25.7–25.2)
P-trend		<0.001		<0.001

[1] Values are mean (95% CI). Results from a linear regression model were adjusted for mean values of age, baseline total energy intake (kcal), alcohol intake (g/d), vegetable consumption (g/d), fruit consumption (g/d), consumption of grains (g/d), physical activity level, smoking status, level of education, and dieting habits in the past 5 y.
[2] Number of participants at baseline (1986).
[3] Ranges of total meat consumption (g/d) in men: Q1, ≤74; Q2, 75–93; Q3, 94–108; Q4, 109–136; and Q5, 137–296; in women: Q1, ≤62; Q2, 63–84; Q3, 85–101; Q4, 102–122; and Q5,123–280.

TABLE 3 BMI at baseline (1986) and in 1992 in subcohort members of the Netherlands Cohort Study[1,2]

Year	Men		Women	
	n	BMI, kg/m²	n	BMI, kg/m²
1986	1991	24.9 ± 0.06	1911	25.0 ± 0.08
1992	1692	25.0 ± 0.06	1678	25.2 ± 0.08*
2000	938	25.0 ± 0.08	958	25.4 ± 0.10*

[1] Values are mean ± SE. *Different from baseline, $P < 0.05$.
[2] BMI derived from a linear mixed model including BMI and time.

(g/d), grain and grain product consumption (e.g., rice, cereals, oats, noodles; g/d), fruit consumption (g/d), and vegetable consumption (g/d). We additionally adjusted for special dieting habits (on doctor's advice) in the 5 y preceding the baseline questionnaire (yes/no). To additionally examine the independent contribution of the individual meat categories (total fresh meat, fresh red meat, beef, pork, minced meat, chicken, and liver), a 4th model was created in which the complementary meat items were also included in the respective multivariable models. To enable comparison, the age- and energy-adjusted analyses were restricted to participants included in multivariable-adjusted analyses (e.g., with no missing values on confounding variables; n = 3902).

Although LME models should be robust to missing values, we conducted the initial analysis excluding individuals with missing BMI at one or two time points (n = 1855 remaining). To evaluate potential bias linked to diet modification (related to disease) during follow-up, we excluded individuals who developed cancer between 1986 and 2000 (n = 2878 remaining). We investigated for all longitudinal analyses whether an association was present both in individuals with a high and low BMI at baseline by performing stratified analyses using median BMI at baseline (women: 24.49; men: 24.76) as cutpoints. We also examined whether similar associations were found across the age spectrum of our subcohort by stratifying our initial analyses in 3 age categories (54–59, 60–64, and 65–70 y).

In addition, we compared the prospective results to the association between meat consumption and change in BMI between age 20 y and baseline, assuming that meat consumption at baseline reflects that during adulthood. This secondary analysis was performed using multiple linear regression, in which mean BMI change (age 20 y to baseline) (and 95% CI) were derived, adjusted for all confounders from the LME models and BMI at age 20 y. Trends were evaluated with the Wald test by assigning participants the median value for each level of the categorical exposure variables and this variable was entered as a continuous term in the regression model.

All tests were 2-tailed and differences were regarded as significant at $P < 0.05$ in all analyses.

Results

Meat consumption was higher in men than in women for all investigated meat categories with the exception of chicken intake, which was similar among both sexes (**Table 1**). Compared with women, men consumed more calories, drank more alcohol, and comprised a higher proportion of former and current smokers. For both men and women, higher total fresh meat consumption was correlated with higher total energy intake, a younger age, a higher BMI, and a higher consumption of alcohol. In contrast to men, body height was not correlated with total fresh meat consumption in women.

A significant trend of increasing baseline BMI with increasing total fresh meat consumption was observed in both men and women (**Table 2**). In both sexes, those with the highest meat intake also had the highest BMI at baseline. Although BMI did not change over time in men, BMI in women increased, with 0.19 and 0.42 kg/m² from baseline to 6 and 14 y of follow-up, respectively ($P < 0.05$) (**Table 3**).

The course of BMI change from baseline until 14 y of follow-up adjusted for confounding variables is depicted by quintiles of total fresh meat consumption (**Fig. 1**) and frequency of meat consumption (**Fig. 2**). The BMI of men increased only modestly after 14 y from baseline for all categories and quintiles of intake (BMI change highest vs. lowest quintile after 14 y: −0.06 kg/m²; P = 0.75) and no clear association between quintiles of intake and BMI change was observed (P-trend = 0.77). In women, BMI increased in each quintile and frequency of intake over time (BMI change highest vs. lowest quintile after 14 y: 0.26 kg/m²; P = 0.20), with a tendency for the highest increase in those with the highest meat consumption. Nonetheless, no significant differ-

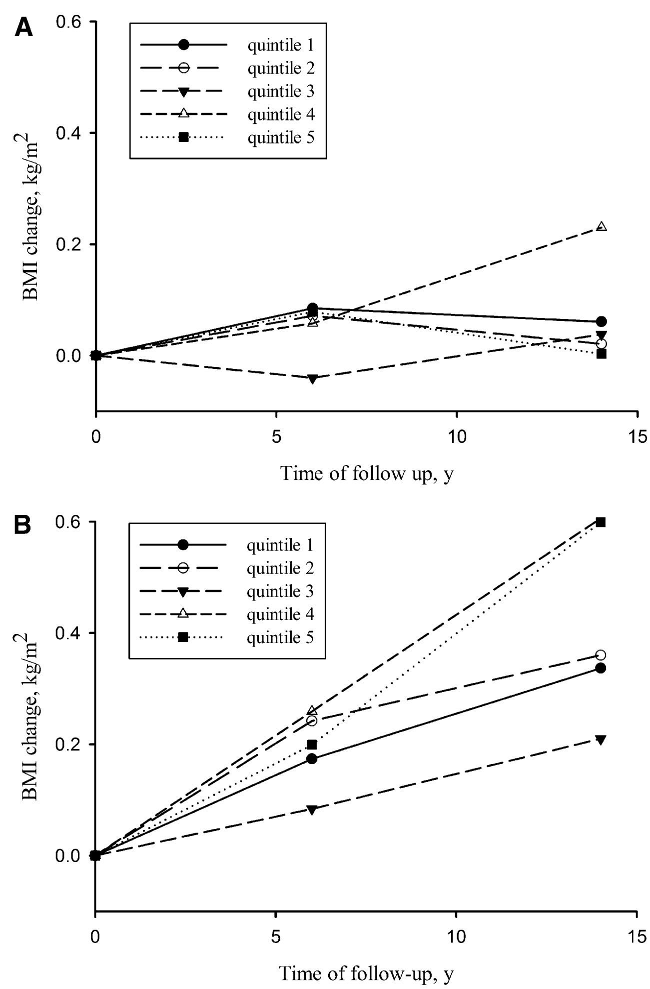

FIGURE 1 Change in BMI over 14 y by quintile of baseline total fresh meat intake in men (*A*) and women (*B*) from the subcohort of the Netherlands Cohort Study. Values are means. Graphs were derived from linear mixed models adjusted for age (y), total energy intake (kcal/d), physical activity level (<30, 30–60, 60–90, >90 min/d), smoking status (never, former, and current smoker), alcohol consumption (g/d), level of education (low, medium, high), vegetable consumption (g/d), fruit consumption (g/d), consumption of grains (g/d), and special dieting habits (yes or no to being on a diet in the past 5 y). Total meat includes all types of meat (except processed meat) and poultry. P-trend for overall differences in BMI changes over time were 0.77 (men) and 0.46 (women). Ranges of total meat consumption (g/d) in men: Q1, ≤74; Q2, 75–93; Q3, 94–108; Q4, 109–136; and Q5, 137–296; in women: Q1, ≤62; Q2, 63–84; Q3, 85–101; Q4, 102–122; and Q5,123–280.

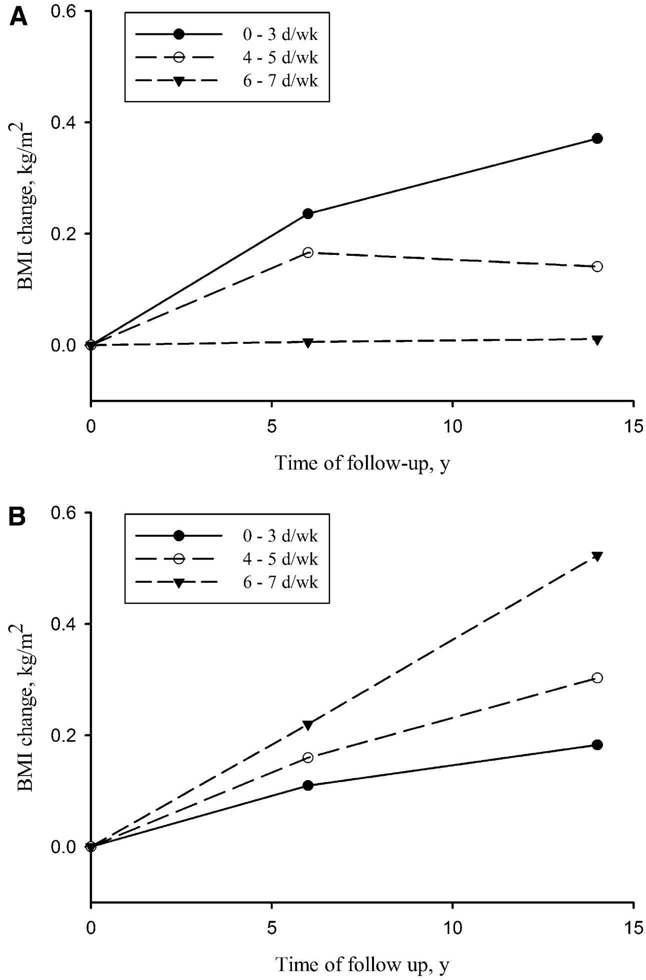

FIGURE 2 Change in BMI over 14 y by quintile of baseline total fresh meat intake in men (A) and women (B) from the subcohort of the Netherlands Cohort Study. Values are means. Graphs were derived from linear mixed models adjusted for age (y), total energy intake (kcal/d), physical activity level (<30, 30–60, 60–90, >90 min/d), smoking status (never, former, and current smoker), alcohol consumption (g/d), level of education (low, medium, high), vegetable consumption (g/d), fruit consumption (g/d), consumption of grains (g/d), and special dieting habits (yes or no to being on a diet in the past 5 y). Total meat includes all types of meat (except processed meat) and poultry. *P*-trend for overall differences in BMI changes over time were 0.77 (men) and 0.46 (women).

ences between quintiles (*P*-trend = 0.46) and frequencies (*P*-trend = 0.40) of total meat intake were observed.

The association between BMI change between baseline and 6 and 14 y of follow-up and specific subtypes of meat was examined by using four different models (unadjusted, age-adjusted, confounders-adjusted, and adjusted for confounders and complementary meat items), which yielded comparable results. The findings for the confounder-adjusted model stratified by sex, according to quintiles and categories of intake (**Table 4**), can be interpreted as the change in BMI in each quintile/category at a given follow-up time compared to baseline. Men with the highest beef intake had a significantly lower increase in BMI than did men in the lowest quintile both after 6 and 14y and a borderline significant trend was observed ($P = 0.06$). Women in the highest quintile of pork consumption had a greater increase in BMI than did women in the lowest quintile after 14 y ($P = 0.02$). In addition, women and men with the highest chicken consumption had a greater increase in BMI compared to those with the lowest intake after 14 y (men, $P = 0.03$; women, $P = 0.05$).

When stratifying our data on median BMI at baseline, we observed virtually similar associations between (subtypes) of meat intake and changes in BMI (results not shown). Our age-stratified (54–59, 60–64, and 65–70 y) analyses yielded mixed results for several subtypes of meat, possibly due to smaller numbers in the age categories (results not shown).

When excluding participants with missing BMI measurements at one or two time points, results attenuated slightly for beef, pork and chicken, although the observed pattern across quintiles remained similar. Other results did not change noticeably. Our findings also did not change when individuals who developed cancer after 1986 were excluded (data not shown).

When retrospectively examining the association between meat consumption reported at baseline and weight change from age 20 y (reported at baseline) to baseline (age 55–69 y), we observed a positive linear trend across all quintiles of total meat consumption in both men and women (*P*-trend < 0.001) (**Table 5**). Similar associations were observed for nearly all subtypes of meat, although consumption of processed meat was not associated with this long-term weight change in men (*P*-trend = 0.73).

Discussion

This large-scale observational study among 55- to 69-y-old men and women showed no evidence of a prospective association between total meat consumption and subsequent changes in BMI over 14 y of follow-up. Different effects for several subtypes of meat were found, which is in line with the current divergent hypotheses regarding the role of meat consumption in body weight management, and indirectly stress the need for the subtype analyses reported herein.

Although the global rates of overweight and obesity are steadily increasing, we observed only a small overall increase in BMI during the 14 y of follow-up. This is consistent with previous studies showing that men and women predominantly gain weight until middle age (33,34). Furthermore, we did not find any evidence for an association between total (fresh) meat consumption and subsequent change in BMI in this population. This would suggest that the largest weight-modifying effect of meat intake, if present, might have taken place earlier in adulthood. However, our age-stratified (54–59, 60–64, and 65–70 y) analyses were not indicative of a clear interaction-effect with age. Recent results from the European Prospective Investigation into Cancer and Nutrition (EPIC)-PANACEA study on the association between various meat products and 5-y weight change including participants from a wider age range (25–70 y) showed the strongest association between weight and red meat intake in participants aged <35 or >65 y and with poultry consumption in participants aged >45 y (21). The few other observational studies on the association between total meat consumption and prospective weight gain report an overall tendency for a positive association (14–17,21). Two studies investigated the possible role of vegetarianism in relation to weight change but observed only small (12) or nonsignificant mixed results (13). Yet, the length of follow-up (2–10 y) in these studies was relatively short and the quality of meat consumption assessment differed considerable between these studies, varying from comprehensive FFQ (14,15,21) to food category-based assessments (16,17).

Our study is the first to our knowledge to further distinguish between the different components of red meat consumption and reports an inverse association between beef consumption and

TABLE 4 Change in BMI from baseline (1986) over time associated with specific dietary meat intakes by quintile or category of meat intake for subcohort members of the Netherlands Cohort Study[1]

	Quintile or category[2]					
	1	2	3	4	5	*P*-trend[3]
Men (*n* = 1991)						
Fresh red meat,[4] *g/d*						
1992	0.15 ± 0.08	0.12 ± 0.13	−0.03 ± 0.12	0.04 ± 0.12	0.01 ± 0.12	
2000	0.23 ± 0.13	0.13 ± 0.11	0.06 ± 0.11	0.08 ± 0.11	−0.11 ± 0.11	0.59
Beef, *g/d*						
1992	0.18 ± 0.08	0.11 ± 0.12	0.09 ± 0.13	−0.21 ± 0.12	−0.09 ± 0.13**	
2000	0.33 ± 0.13	0.12 ± 0.11	0.19 ± 0.11	−0.01 ± 0.11	−0.27 ± 0.11**	0.06
Pork, *g/d*						
1992	0.15 ± 0.08	0.03 ± 0.12	0.06 ± 0.13	0.08 ± 0.12	−0.06 ± 0.12	
2000	−0.04 ± 0.13	−0.01 ± 0.11	0.14 ± 0.11	0.12 ± 0.11	0.11 ± 0.11	0.39
Minced meat,[5] *g/d*						
1992	0.03 ± 0.08	0.01 ± 0.13	−0.07 ± 0.12	0.07 ± 0.12	0.22 ± 0.21	
2000	0.18 ± 0.13	0.06 ± 0.11	−0.08 ± 0.11	0.24 ± 0.11	−0.02 ± 0.11	0.05
Processed meat, *g/d*						
1992	0.15 ± 0.08	0.07 ± 0.13	−0.05 ± 0.12	0.01 ± 0.12	0.07 ± 0.12	
2000	0.07 ± 0.13	0.00 ± 0.11	0.19 ± 0.11	0.07 ± 0.11	0.02 ± 0.11	0.41
Chicken, *g/d*						
1992	0.02 ± 0.07	−0.02 ± 0.11	0.05 ± 0.11	0.13 ± 0.10		
2000	−0.17 ± 0.12	−0.09 ± 0.10	0.29 ± 0.10*	0.19 ± 0.09*		0.04
Fish, *g/d*						
1992	−0.03 ± 0.07	−0.01 ± 0.12	0.09 ± 0.10	0.14 ± 0.12		
2000	−0.03 ± 0.11	−0.06 ± 0.10	0.12 ± 0.09	0.28 ± 0.11		0.39
Women (*n* = 1911)						
Fresh red meat,[4] *g/d*						
1992	0.18 ± 0.09	0.25 ± 0.14	0.22 ± 0.14	0.09 ± 0.14	0.23 ± 0.14	
2000	0.26 ± 0.14	0.42 ± 0.12	0.50 ± 0.12	0.37 ± 0.12	0.55 ± 0.12	0.79
Beef, *g/d*						
1992	0.13 ± 0.09	0.33 ± 0.14	0.33 ± 0.14	0.06 ± 0.14	0.23 ± 0.14	
2000	0.39 ± 0.15	0.44 ± 0.12	0.58 ± 0.12	0.41 ± 0.12	0.24 ± 0.13	0.16
Pork, *g/d*						
1992	0.21 ± 0.09	0.22 ± 0.15	0.22 ± 0.14	0.09 ± 0.14	0.23 ± 0.14	
2000	0.13 ± 0.14	0.52 ± 0.13	0.46 ± 0.12	0.39 ± 0.12	0.60 ± 0.13*	0.29
Minced meat,[5] *g/d*						
1992	0.14 ± 0.09	0.12 ± 0.14	0.19 ± 0.14	0.30 ± 0.14	0.21 ± 0.15	
2000	0.43 ± 0.15	0.44 ± 0.12	0.36 ± 0.12	0.46 ± 0.12	0.41 ± 0.13	0.88
Processed meat, *g/d*						
1992	0.13 ± 0.09	0.13 ± 0.14	0.27 ± 0.15	0.34 ± 0.14	0.10 ± 0.14	
2000	0.28 ± 0.14	0.44 ± 0.12	0.46 ± 0.13	0.61 ± 0.12	0.29 ± 0.12	0.51
Chicken, *g/d*						
1992	0.04 ± 0.08	0.28 ± 0.12*	0.16 ± 0.13	0.26 ± 0.12		
2000	0.17 ± 0.14	0.47 ± 0.10	0.47 ± 0.11	0.53 ± 0.11*		0.28
Fish, *g/d*						
1992	0.16 ± 0.07	0.17 ± 0.13	0.28 ± 0.12	0.13 ± 0.16		
2000	0.30 ± 0.12	0.54 ± 0.11	0.54 ± 0.10	0.23 ± 0.14		0.43

[1] Values are mean ± SE. Results from a linear mixed model were adjusted for age, baseline total energy intake (kcal), physical activity level (<30, 30–60, 60–90, >90 min/d), smoking status (never, former, and current smoker), alcohol intake (g/d), level of education (low, medium, high), vegetable consumption (g/d), fruit consumption (g/d), consumption of grains (g/d), and dieting habits (yes or no to being on a diet in the past 5 y). **Lower BMI increase than lowest quintile or category of intake, *P*-interaction < 0.05.*Higher BMI increase than lowest quintile or category of intake, *P*-interaction < 0.05.

[2] Range of total fresh meat consumption (g/d) for men: Q1, ≤75; Q2, 745–94; Q3, 94–108; Q4, 108–137; and Q5, 137–296. Range of total fresh meat consumption (g/d) for women: Q1, ≤63; Q2, 63–84; Q3, 84–101; Q4, 101–123; and Q5, 123–280.

[3] Test for overall difference in BMI increase over time between groups of meat intake

[4] Including beef, pork, minced meat, liver, and other meat

[5] Including beef and pork

TABLE 5 Change in BMI from age 20 y to baseline (1986) by quintile or category of intake of fresh meat, types of fresh meat, and processed meat and fish measured at baseline in the subcohort members of the Netherlands Cohort Study[1]

Food item	*n*	Men (*n* = 1598)	*n*	Women (*n* = 1736)
		Change in BMI (95% CI)		Change in BMI (95% CI)
Total fresh meat,[2] *g/d*				
1[3]	303	2.82 (2.62–3.02)	349	2.75 (2.50–3.00)
2	322	3.10 (2.97–3.23)	337	3.30 (3.13–3.46)
3	332	3.24 (3.13–3.36)	358	3.60 (3.46–3.75)
4	323	3.40 (3.27–3.52)	351	3.88 (3.72–4.04)
5	318	3.79 (3.57–4.01)	341	4.55 (3.29–4.82)
P-trend		<0.001		<0.001
Fresh red meat,[4] *g/d*				
1[3]	304	2.83 (2.63–3.02)	346	2.86 (2.61–3.10)
2	317	3.09 (2.95–3.22)	345	3.31 (3.14–3.47)
3	330	3.24 (3.12–3.35)	343	3.58 (3.45–2.73)
4	322	3.40 (3.28–3.53)	356	3.84 (3.69–4.00)
5	325	3.78 (3.57–4.01)	346	4.47 (3.21–4.74)
P-trend		<0.001		<0.001
Beef, *g/d*				
1[3]	306	3.11 (2.94–3.28)	342	3.44 (3.23–3.66)
2	321	3.18 (3.03–3.32)	355	3.51 (3.33–3.68)
3	314	3.24 (3.12–3.36)	337	3.57 (3.42–3.72)
4	334	3.32 (3.19–3.44)	349	3.67 (3.51–3.82)
5	323	3.52 (3.30–3.74)	353	3.88 (3.60–4.15)
P-trend		0.07		0.07
Pork, *g/d*				
1[3]	303	3.08 (2.90–3.27)	352	3.13 (2.90–3.36)
2	321	3.17 (3.03–3.31)	339	3.35 (3.17–3.52)
3	316	3.24 (3.13–3.37)	359	3.55 (3.40–3.70)
4	341	3.32 (3.20–3.45)	347	3.77 (3.62–3.93)
5	317	3.53 (3.30–3.75)	339	4.29 (4.01–4.56)
P-trend		0.06		<0.001
Minced meat,[5] *g/d*				
1[3]	299	3.05 (2.88–3.22)	337	4.45 (3.24–3.67)
2	330	3.14 (3.00–3.28)	357	3.52 (3.35–3.69)
3	324	3.23 (3.11–3.35)	367	3.58 (3.43–3.73)
4	319	3.33 (3.21–3.46)	344	3.67 (3.51–3.82)
5	326	3.60 (3.39–3.81)	331	3.87 (3.59–4.16)
P-trend		0.03		0.01
Chicken,[6] *g/d*				
1[3]	345	3.23 (3.07–3.40)	391	3.40 (3.20–3.60)
2	375	3.25 (3.11–3.39)	461	3.49 (3.32–3.66)
3	419	3.28 (3.16–3.39)	414	3.62 (3.47–3.77)
4	459	3.33 (3.14–3.51)	470	3.91 (3.68–4.15)
P-trend		0.06		0.01
Processed meat, *g/d*				
1[3]	300	3.15 (2.99–3.33)	357	3.41 (3.21–3.61)
2	332	3.20 (3.05–3.34)	339	3.47 (3.29–3.65)
3	311	3.24 (3.12–3.36)	347	3.55 (3.39–3.70)
4	322	3.29 (3.18–3.42)	350	3.67 (3.62–3.82)
5	333	3.47 (3.24–3.70)	343	3.98 (3.70–4.27)
P-trend		0.73		<0.001
Fish,[6] *g/d*				
1[3]	379	3.21 (3.05–3.37)	539	3.40 (3.21–3.60)
2	367	3.24 (3.10–3.37)	379	3.50 (3.33–3.66)
3	507	3.28 (3.16–3.40)	520	3.68 (3.53–3.84)
4	345	3.38 (3.17–3.59)	299	4.02 (3.73–4.30)
P-trend		0.02		0.01

[1] Values are mean (95% CI). Results were derived from a linear regression model adjusted for age, baseline total energy intake (kcal), alcohol intake (g/d), vegetable consumption (g/d), fruit consumption (g/d), consumption of grains (g/d), physical activity level, smoking status, level of education, dieting habits in the past 5 y, and BMI at age 20 y.
[2] Including all types of meat (except processed meat) and poultry.
[3] Reference category.
[4] Including beef, pork, minced meat, liver, and other meat.
[5] Including beef and pork.
[6] Categorical cutpoints are for chicken: 0, 0–13.2, 13.2–22.8, ≥22.8 g/d; fish: 0, 0–10, 10–20, ≥20 g/d.

prospective changes in BMI in men. However, this beneficial effect on body weight was only present in participants with very high intakes and attenuates below a consumption level of 40 g/d, thereby likely reflecting a dietary pattern in the extremes. Although beef consumption was positively correlated with a dietary pattern high in cooked leafy vegetables, cabbages, legumes, and carrots and inversely correlated with a pattern high in pork, processed meat, and potatoes, adjustment for these patterns did not noticeably change the results (results not shown). In contrast, in women, the highest quintile of pork consumption was associated with a 0.60-kg/m^2 higher increase in BMI compared to the lowest intake after 14 y of follow-up. The differences in nutritional content between beef and pork (e.g., the fat:protein ratio) may have resulted in these different weight-inducing effects. Previous longitudinal studies examining changes in body weight (21) or weight circumference (19,35) in relation to red meat consumption in general showed contrasting results, but none of the reports specified the relative intakes of the individual components of red meat.

Our data suggest that men and women with the highest chicken consumption (>22.8 g/d) had a 0.19- and 0.53-kg/m^2 higher increase in BMI after 14 y of follow-up, respectively, compared to those who consumed no chicken at all. This is in line with recent results from a Danish study showing that high consumption of chicken was associated with greater weight gain at the waist after 5 y of follow-up in women, but not in men (19). The EPIC-PANACEA study recently reported a strong positive association between prospective weight change and chicken consumption, but this was mainly driven by participants with previous illness or weight loss attempts that resulted in changes in diet (21). However, when we adjusted our analyses for special dieting habits (on doctor's advice) in the 5 y preceding the baseline questionnaire or excluded participants who developed cancer during follow-up, the results did not appreciably change.

The discrepancy between our cross-sectional and prospective results raises the question during which age period the differences in BMI across the meat consumption spectrum develop. This prompted us to retrospectively examine the association between meat consumption at baseline and change in body weight between age 20 y and baseline (55–69 y). It should be noted, however, that we only had baseline data on meat intake and used long-term recall of early adulthood weight. Although earlier studies indicate that the remote recall of weight by elderly participants is overall accurate and independent of current weight status (36,37) and that, in addition, there is no reason to assume differential recall bias with respect to meat consumption at baseline, we cannot empirically test these assumptions at present. However, in case these assumptions do hold, our results suggest that meat consumption or factors directly related to meat consumption are positively associated with weight change over the first 40 y of adult life. Studies specifically designed to examine long-term prospective weight change that combine multiple dietary and anthropometric assessments are needed to verify these results.

We must be careful when drawing causal inferences from both our prospective and retrospective findings given that BMI is influenced by multiple, connected, dietary and nondietary factors of which meat consumption is only one. However, our large-scale study does provide relevant clues for further research and public health practice in regard to identifying modifiable dietary determinants of obesity. The dietary pattern of our subcohort and the types of meat consumed are likely population- and time-specific and consumption of subtypes of meat is likely to be less stable over time than total meat intake. We cannot completely exclude the possibility that individuals with the lowest total meat intake may have had an overall healthier lifestyle than did those with the highest intake, resulting in less of a BMI increase over time. Nevertheless, when we attempted to control for further potential confounding in our model by accounting for intake of vegetables, fruit, grain content of the diet, and dieting habits, our observations did not appreciably change. We made use of a FFQ to determine meat consumption, which was found to correlate well with a measurement using dietary records (38) but is nonetheless susceptible for measurement error (39). We were not able to account for changes in physical activity or dietary intake, which is likely to occur with aging. However, the validity of the FFQ has been tested and shown to be representative for dietary habits over a period of at least 5 y (40). Self-reported height and weight measurements recorded in the questionnaire were not validated within the NLCS, but previous studies provide sufficient evidence to presume that these are reliable and valid tools to ascertain body weight and height in large-scale prospective studies (41–43). Nevertheless, the prevalence of overweight might have been underestimated, especially because body height is known to decrease and body composition is likely to change in older age (44). Because we had only BMI measurements, we could not distinguish between changes in lean tissue or fat mass, a shortcoming of many observational studies that is currently debated in the literature (45,46). However, several studies reported similar findings when comparing changes in BMI to changes in waist circumference, a proxy of abdominal adiposity. Generalization of our results to younger populations may be hampered, because ageing is accompanied by specific changes in body composition and metabolic function that could have affected our findings. Body weight is likely to fluctuate over time, resulting in successive periods of weight loss and gain (47,48). Our long-term follow-up including three consecutive self-reports reduces the influence of such weight cycling on the study results. Because of the older age group of our population at baseline, many subcohort members had only one or two prospective measurements available for analysis. Although it is likely that those who remained alive until the last follow-up point tended to be healthier than the entire subcohort, there was no indication that survivorship bias distorted our results.

Our data suggest that the association between meat consumption and BMI change during the 14-y prospective follow-up in older adults depends on the type of meat consumed. Total meat consumption, or factors directly related to total meat intake, was not strongly associated with weight change during the 14-y prospective follow-up in this elderly population. However, different effects for several subtypes of meat were found. Overall, more observational and intervention research is needed to verify our prospective, retrospective, and subtype observations and to further elucidate the role of (subtypes of) meat in weight management and its implications for public health practice.

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and T.A. assisted with the analyses and data interpretation; A.M.J.G. drafted the manuscript; M.P.W., L.J.S., P.C.D., L.A.E.H., P.A.v.d.B., and R.A.G. critically revised the manuscript; and A.M.J.G. had primary responsibility for the final content. All authors read and approved the final manuscript.

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