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Longitudinal association between animal and vegetable protein intake and obesity among adult males in the United States: the Chicago Western Electric Study

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Abstract

Literature on the association of protein intake with body weight is inconsistent. Little is known about the relation of long-term protein intake to obesity. This study aimed to determine the association between protein intake and obesity. A cohort of 1,730 employed white men ages 40–55 years from the Chicago Western Electric Study was followed from 1958 to 1966. Diet was assessed twice with Burke's comprehensive diet history method, at two baseline examinations; height, weight, and other covariates were measured annually by trained interviewers. Generalized estimating equation (GEE) was used to examine the relation of baseline total, animal, and vegetable protein intake to likelihood of being overweight or obese at sequential annual examinations. Dietary animal protein was positively related to overweight and obesity over seven years of follow up. With adjustment for potential confounders (age, education, cigarette smoking, alcohol intake, energy, carbohydrate and saturated fat intake, and history of diabetes or other chronic disease), the odds ratios (95% confidence intervals) for obesity were 4.62 (2.68–7.98, p for trend<0.01) for participants in the highest compared to the lowest quartile of animal protein and 0.58 (0.36, 0.95, p for trend=0.053) for those in the highest quartile of vegetable protein intake. A statistically significant, positive association was seen between animal protein intake and obesity; those in higher quartiles of vegetable protein intake had lower odds of being obese. These results indicate that animal and vegetable protein may relate differently to occurrence of obesity in the long run.

Keywords

Dietary protein intake; overweight; obesity; nutrition; epidemiology

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INTRODUCTION

Although weight loss diets promoting higher intake of protein and restricting intake of carbohydrates are popular, available information on protein intake and body weight remains inconsistent. Results of some studies indicate that dietary composition, i.e., relative amounts of protein, carbohydrate, and fat in the diet, may influence weight loss or weight maintenance in overweight and/or obese individuals (1–4), but others have yielded contrary findings (5–9). While some research indicates that protein's role in weight loss may be the result of increased satiety and decreased energy intake (4), other studies suggest that protein benefits body weight because it improves glycemic control (5, 6), increases lean muscle mass (6, 10–11), or increases thermogenesis (9, 12–13). A recent trial in overweight adults found no statistically significant association of diet composition with achieved weight loss (14). Long-term data on protein intake and body weight are lacking. Most studies investigating protein intake and body weight have had limited follow-up ranging from several weeks to one year; few studies extend to two years or longer (14). In addition, none of these studies examined animal protein and vegetable protein separately. Given their differences in amino acid composition (15), vegetable and animal protein may have different effects on body weight. Therefore, we prospectively examined the long-term association of protein (total, animal, and vegetable) intake with overweight and obesity among middle-aged male employees of the Chicago Western Electric Company.

METHODS

Study Population

The Chicago Western Electric Study is a prospective cohort study of 2107 employed men ages 40–55 years at baseline in 1957–1958, designed primarily to examine coronary heart disease and its predictors. Participants held positions for at least two years related to telephone manufacturing at the Chicago Western Electric Company Hawthorne Works. Recruitment, participant demographics, and procedures for baseline and follow up examinations have been described (16–17). Clinical data and information on age, education, occupation, religion, and anthropometric measurements were collected at baseline and annual follow-up examinations through 1966. All seven annual follow-up examinations were completed by 1524 (88%) of 1730 participants through 1966. The remainder completed at least four examinations from 1960–1966.

Of the original 2107 participants, 229 men were excluded because of missing data on diet (n = 187) or education (n = 42). Participants were also excluded if they had not completed at least four (of seven) follow-up examinations (n = 148). A total of 1730 men remained for analysis.

This study was reviewed and approved by the Institutional Review Board at the University of North Carolina, Chapel Hill.

Dietary Assessment

Dietary information was obtained twice by two nutritionists at baseline in 1957–58 and initial follow-up examination one year later. Mean nutrient data were used from the two examinations to decrease classification error. Standardized interviews and questionnaires were completed according to Burke's comprehensive dietary history method (18). Participants were asked about foods typically consumed, time and place of meals, weekday and weekend eating patterns, special diets, and changes in eating habits over the preceding 20 years. In addition, a detailed cross-check was completed for 195 specific food items to ascertain the frequency of consumption and amount consumed for each food in the previous 28 days. Models of commonly consumed foods and dishes of various sizes were provided for reference. Questionnaires were mailed to participants' wives regarding home food preparation; these were returned by participants at their interview. Information on foods and standard portion sizes for cafeteria items was obtained from the company dietary department. Details regarding food preparation were also gathered from local bakeries and restaurants. For reported items not among the 195 specific foods, nutritionists obtained recipes and analyzed their components for nutrient content. Data were not collected on dietary supplement use, presumed to be infrequent in the 1950s.

Dietary data were coded by nutritionists to indicate types and quantities of foods and beverages consumed during the preceding 28 days. Food tables derived from several sources (19–21) were used to calculate participants' daily intake of energy, protein (animal and vegetable), fat (animal and vegetable), carbohydrates, alcohol, iron, calcium, phosphorus, thiamin, riboflavin, niacin, and vitamins A, C, and D. Total polyunsaturated fatty acid intake was estimated by summing intake of arachidonic, linoleic, and linolenic acid (22–23). Data on some nutrients (e.g., fiber, sodium, and potassium) were not available because of technical limitations at the time of the study.

Outcomes

The outcomes for this study were overweight (inclusive of obesity) and obesity at a given examination, defined as BMI ≥ 25.0 kg/m^2 and BMI ≥ 30.0 kg/m^2, respectively.

Statistical Analyses

The Generalized Estimating Equation (GEE) for longitudinal data (24) was used to examine the association between quartile of average protein intake (animal, vegetable, and total protein) from the two diet assessments and overweight/obesity using BMI measurements from all annual examinations, with adjustment for potential confounders. These models contained only one type of protein, so that variables representing part and whole (e.g., vegetable protein and total protein) were not included in the same analysis. The relation of each protein type to longitudinal weight status was assessed using the coefficient of the interaction term for that variable and time, t (t=0, 1…, 8); these interaction terms were not significant and were excluded from final models. Initial models assessed age, and total energy intake as covariates. The covariates assessed in each final model included age (years), education (years), current smoking status (yes/no), heavy alcohol intake (yes/no) (defined as ≥ two drinks per day), total energy intake, saturated fat and carbohydrate intake (percent of total caloric intake), and history of chronic disease, including myocardial infarction or diabetes mellitus. Results are expressed as prospective odds ratios [ORs] (95% confidence intervals [CIs]) for the association between quartile of protein by type with overweight and obesity. For univariate analyses (Table 1), a p-value of less than 0.05 was considered statistically significant. For multivariate analyses (Table 2), odds ratio confidence intervals that did not include a value of 1.0 or p-values < 0.05 were considered statistically significant. All analyses were performed using SAS version 9.1.3 (SAS Institute Inc, Cary, NC).

RESULTS

Baseline data

Average age was 47.6 years (standard deviation = 4.4); average BMI, 25.5 kg/m^2 (± 3.1) (Table 1); a majority (54.2%) of participants were overweight or obese. About one half smoked, and most (93.6%) reported consuming alcohol. The proportion of participants who were overweight and obese at baseline was higher over quartiles of animal protein intake (p-trend <0.01 for both). A similar pattern prevailed for vegetable protein, although this trend was not statistically significant. The primary sources of animal protein were beef, veal, and lamb. Alcohol intake (ml/day) and the proportion of participants who reported heavy alcohol use were lower with quartile of animal protein intake; the reverse was true for vegetable protein. A statistically significant trend was observed for lower total energy intake over quartiles of animal protein intake; this trend was not observed for vegetable protein. Intakes of total fat and saturated fat were higher with higher intake of animal protein and lower at higher levels of vegetable protein intake. Results from partial correlation analysis of energy intake, nutritional variables, and BMI (adjusted for age, education, and smoking as potential confounders) are shown in online Table 1.

Follow up data

In multivariable analyses controlled for age, energy, carbohydrate and saturated fat intake, education, cigarette smoking, alcohol intake, and history of chronic disease or diabetes, animal protein intake was positively associated with both overweight and obesity. The ORs (95% CIs) for the highest vs. lowest quartiles of animal protein intake for overweight and obesity were 2.09 (1.55, 2.81) and 4.62 (2.68, 7.98), respectively; p-values for both trends were <0.01 (Table 2). No statistically significant association was observed between vegetable protein quartile and overweight for participants in the second, third, and fourth quartiles (OR range = 1.07–1.11), but those in the higher quartiles of vegetable protein intake were less likely to be obese than those in the lowest quartile (quartile four OR: 0.58; 95% CI: 0.36, 0.95; p for trend=0.053).

Analyses were also performed using the three protein types and BMI as continuous variables. In the multivariable-adjusted model, total protein and animal protein were positively associated with BMI (Supplemental Table 1). The inverse relation between vegetable protein and BMI was attenuated and became statistically non-significant.

Sensitivity analyses were conducted to ascertain the potential effect of missing BMI values on our findings (data not shown). Separate analyses were run for missing and imputed BMI values using the row deleting and last observation carrying forward (LOCF) methods, respectively. Results for these two methods did not differ appreciably from the above, with negligible changes in p-values for all models. In addition, with both animal and vegetable protein in the models, a statistically significant positive association between animal protein and overweight/obesity remained (Supplemental Table 2). The nonsignificant inverse association for vegetable protein persisted; this may be partially explained by statistically significant, inverse correlations between saturated fat and vegetable protein, and saturated fat and BMI. In addition, in the sensitivity analyses, we considered several micronutrients (calcium, iron, phosphorus, vitamin A, thiamin, riboflavin, and niacin). Our findings were not appreciably altered. Further sensitivity analyses were performed to determine the potential role of total fat and other types of fat (polyunsaturated and monounsaturated) in the observed associations. The inclusion of these terms in our models did not materially change our results.

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DISCUSSION

In this seven-year follow-up study, animal protein intake was positively related and vegetable protein intake inversely associated with overweight/obesity in apparently healthy middle-aged American men. Our results indicate that protein sources may be important with respect to weight, independent of energy, carbohydrate, alcohol, and fat intake.

Our results are in apparent contrast with findings from several short-term clinical trials that have shown an inverse association (1–4, 25–27) or no association (5–9, 14) between protein intake and body weight. However, these studies focused on total protein rather than types of protein or protein sources. Little is known about the differential effect of protein source on

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long term body weight. If animal protein and vegetable protein have different influences on weight, results may vary across studies depending on the dietary content of animal and vegetable protein. Specifically, protein from animal and vegetable sources varies in amino acid composition. For example, in one study examining protein intake and blood pressure, individuals consuming a high vegetable/low animal protein diet consumed substantially greater amounts of glutamic acid, cystine, and proline compared to those consuming a low vegetable/high animal protein diet (15). Further, the follow-up periods of previous studies ranged from several weeks or months (in most cases) to two years, compared with seven years of follow up for the present study. Metabolic changes due to alterations in amount/type of dietary protein may vary over the long term. Thus, results from previous studies may have differed had participants been observed for a longer duration. Also, methodology for assessing dietary intake differed from that of the Western Electric Study. Burke's comprehensive diet history was used to assess dietary intake for this study, while 24-hour dietary recalls are widely used in recent epidemiologic research. Variations in these methodologies may have led to differences in dietary information captured. In addition, the aforementioned studies were clinical trials, while our study is observational in nature. The randomized design of clinical trials minimizes residual confounding, while unmeasured variables cannot be accounted for in observational research. For this research, there may be residual confounding by physical activity or dietary variables such as fiber, for which data were not collected. These possibilities may explain, at least in part, why our findings differ from those yielded by clinical trials. Moreover, previous study samples were comprised only of overweight or obese participants (14) and/or were predominantly (5, 7–9, 14) or exclusively (6) female. Their different results compared to ours may be explained by metabolic differences in overweight and obese compared to normal weight individuals, or in men compared to women, since our study included normal weight participants and men only. Finally, several previous short-term studies were conducted among individuals who were hyperinsulinemic (5, 7) or had been diagnosed with type 2 diabetes (8–9). Some evidence suggests that replacement of dietary carbohydrates with protein, primarily from lean meat, may lead to reduced postprandial insulin, resulting in weight loss (5). It is reasonable to hypothesize that this pathway may function differently in those with impaired glucose tolerance or diabetes compared to those with normal glucose tolerance.

It has been proposed that combined intake of animal protein and fat may accelerate insulin resistance (28). Because our participants consumed a relatively high fat diet and the majority of their protein intake was from animal sources, this potential mechanism may have operated, leading to our findings. Researchers have hypothesized that this acceleration results from increased insulin release stimulated by arginine, histidine, and leucine (abundant in meats, including beef—a main source of animal protein for this study cohort) (29) and a possible association between saturated fatty acid intake and increased insulin response (30). A high fasting respiratory quotient indicating a reduced ability to oxidize fat may be associated with later development of obesity (31–32), and increased insulin secretion may raise respiratory quotient (33). While dietary protein alone stimulates little insulin release, it may substantially increase insulin release when consumed in conjunction with carbohydrates (33).

One strength of the present study is the relatively long-term follow-up period with annual examinations throughout. Long term data on the association between protein intake and overweight/obesity are sparse. Use of GEE along with these data from annual examinations enabled us to capture successive BMI values over time. A second strength of this study is the fairly homogeneous cohort (all men, of similar ethnic backgrounds, and employed in similar work settings with comparable levels of occupational activity), tending to reduce likelihood of confounding from unmeasured factors associated with both protein intake and body weight. For example, at the time the Western Electric study was carried out, adequate measures of physical activity level were not available, thus data on this variable were not collected. Because less was known at that time about the link between physical activity and health, and people did not typically own exercise equipment or actively seek out opportunities for leisure-time activity, our assessment is that activity levels outside of work were relatively low and similar across this homogeneous cohort. Thus, our results should not be substantially biased by sizable inter-participant differences in physical activity at work or during leisure.

In summary, we observed that animal protein intake was positively related to and vegetable protein intake was inversely associated with body mass and overweight/obesity, independent of other dietary macronutrients, in a cohort of American adult men studied longitudinally for seven years. Our results highlight that animal and vegetable protein play different roles in obesity development, and suggest that replacement of animal protein with vegetable protein in the diet may offer promise in future interventions aimed at prevention/control of overweight and obesity. Additional observational and interventional long-term investigation focusing on protein type is warranted, and should examine protein in the context of overall diet including other macronutrients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1

Baseline characteristics of 1730 men, Chicago Western Electric Study, 1957–1959, by quartiles 1 and 4 of total, animal, and vegetable protein intake*

	Total Protein			*Animal Protein*			*Vegetable Protein*		
Characteristic	**Quartile 1 (n =432)**	**Quartile 4 (n = 432)**	**p-value†**	**Quartile1 (n = 432)**	**Quartile 4 (n = 432)**	**p-value†**	**Quartile 1 (n = 429)**	**Quartile 4 (n = 434)**	**p-value†**
Age (yr)	47.2 (4.4)	47.9 (4.3)	0.051	47.3 (4.5)	47.9 (4.4)	0.02	47.7 (4.4)	47.5 (4.4)	0.68
Weight (kg)	75.6 (10.4)	81.1 (10.9)	<0.01	75.6 (10.5)	81.2 (11.0)	<0.01	78.4 (11.2)	77.8 (11.0)	0.50
BMI (weight (kg)/height^2 (m^2))	24.5 (3.0)	26.5 (3.2)	<0.01	24.6 (2.9)	26.5 (3.2)	<0.01	25.4 (3.3)	25.7 (3.2)	0.23
Overweight (BMI ≥ 25, %)	42.1	66.2	<0.01	43.8	66.2	<0.01	52.2	56.2	0.33
Obesity (BMI ≥ 30, %)	4.2	13.7	<0.01	4.4	13.7	<0.01	7.7	8.8	0.63
Current smoker (%)	60.2	50.0	<0.01	59.7	50.5	<0.01	56.2	58.3	0.65
Cigarettes per day	11.2 (10.9)	8.9 (10.9)	<0.01	10.9 (10.8)	9.2 (11.3)	0.02	11.1 (12.0)	10.3 (11.0)	0.29
Heavy alcohol use (%)	6.4	4.8	0.67	6.4	4.8	0.84	6.4	4.8	0.24
Any alcohol use (%)	93.1	94.2	<0.01	92.5	94.1	<0.01	92.8	94.2	<0.01
Alcohol intake (ml/day)	20.6 (26.2)	13.3 (16.9)	<0.01	21.0 (25.9)	12.8 (16.2)	<0.01	14.9 (20.3)	18.8 (22.2)	<0.01
Education (yr)	11.0 (2.3)	11.5 (2.7)	<0.01	10.8 (2.2)	11.5 (2.5)	<0.01	11.7 (2.6)	10.8 (2.4)	<0.01
History of chronic disease (%)	14.6	16.7	0.28	15.3	16.2	0.65	13.3	18.0	0.07
Dietary Intake									
Total energy (kcal)	3270.1 (754.4)	2835.3 (747.6)	<0.01	3276.0 (777.8)	2855.1 (748.6)	<0.01	3165.9 (800.4)	3085.6 (779.0)	0.23
Alcohol (% kcal)	4.4 (5.6)	3.4 (4.3)	<0.01	4.5 (5.5)	3.2 (4.2)	<0.01	3.5 (4.9)	4.1 (4.7)	<0.01
Total fat (% kcal)	41.6 (4.3)	43.4 (4.4)	<0.01	41.3 (4.2)	44.0 (4.3)	<0.01	44.9 (3.8)	41.0 (4.3)	<0.01
Total fat (g/day)	137.9 (42.2)	152.0 (41.7)	<0.01	140.5 (42.3)	150.8 (41.9)	<0.01	158.4 (45.0)	141.2 (40.4)	<0.01
Saturated fatty acids (%kcal)	15.7 (2.3)	16.9 (2.3)	<0.01	15.3 (2.2)	17.2 (2.3)	<0.01	17.9 (2.1)	15.0 (2.0)	<0.01
Polyunsaturated fatty acids (%kcal)	3.9 (0.9)	3.9 (0.9)	0.09	4.0 (0.9)	3.9 (0.9)	0.19	3.8 (0.7)	4.1 (1.0)	<0.01
Dietary cholesterol (mg/day)	692.5 (218.4)	737.1 (255.3)	<0.01	678.2 (217.7)	749.7 (257.1)	<0.01	811.5 (277.7)	660.2 (214.0)	<0.01
Carbohydrate (% kcal)	40.6 (4 .6)	35.4 (4.7)	<0.01	40.8 (4.5)	35.0 (4.5)	<0.01	35.8 (4.7)	39.5 (4.6)	<0.01
Carbohydrate (g/day)	330.4 (78.9)	249.8 (69.3)	<0.01	332.5 (80.3)	249.3 (69.8)	<0.01	283.9 (83.1)	302.9 (78.1)	<0.01
Animal protein (% kcal)	9.2 (0.9)	14.1 (1.5)	<0.01	9.1 (0.8)	14.1 (1.4)	---	12.8 (2.1)	10.6 (1.9)	<0.01
Animal protein (g/day)	75.5 (18.4)	99.4 (27.3)	<0.01	74.7 (18.5)	100.6 (27.1)	---	100.1 (26.6)	80.8 (22.5)	<0.01
Vegetable protein (% kcal)	3.6 (0.5)	3.4 (0.6)	<0.01	3.8 (0.6)	3.2 (0.6)	<0.01	2.8 (0.3)	4.2 (0.4)	---
Vegetable protein (g/day)	29.1 (9.0)	23.7 (7.6)	<0.01	30.9 (9.6)	22.7 (7.2)	<0.01	22.0 (5.9)	32.3 (9.8)	---

	Total Protein			Animal Protein			Vegetable Protein		
Characteristic	**Quartile 1 (n =432)**	**Quartile 4 (n = 432)**	**p-value†**	**Quartile1 (n = 432)**	**Quartile 4 (n = 432)**	**p-value†**	**Quartile 1 (n = 429)**	**Quartile 4 (n = 434)**	**p-value†**
Calcium (g/day)	0.9 (0.4)	1.1 (0.5)	<0.01	0.9 (0.3)	1.1 (0.5)	<0.01	1.2 (0.6)	0.9 (0.3)	<0.01
Phosphorus (g/day)	2.2 (0.8)	2.4 (0.8)	<0.01	2.3 (0.9)	2.4 (0.8)	0.06	2.3 (0.8)	2.5 (0.9)	<0.01
Iron (mg/day)	15.8 (3.6)	17.1 (4.3)	<0.01	16.2 (3.9)	17.0 (4.3)	<0.01	16.5 (4.2)	17.2 (4.3)	0.04
Vitamin A (IU/day)	10181.6 (3533.9)	12015.9 (4439.2)	<0.01 <0.01	10335.0 (4050.1)	11750.4 (4451.4)	<0.01 <0.01	11300.0 (4134.0)	11267.5 4753.8)	0.88 <0.01
Thiamin (mg/day)	1.6 (0.4)	1.6 (0.5)	<0.01	1.6 (0.4)	1.6 (0.5)	<0.01	1.6 (0.5)	1.7 (0.5)	<0.01
Riboflavin (mg/day)	2.2 (0.6)	2.5 (0.8)	<0.01	2.2 (0.6)	2.5 (0.8)	0.011	2.7 (0.9)	2.3 (0.6)	<0.01
Niacin (mg/day)	21.3 (5.2)	23.1 (5.9)	<0.01	22.0 (5.8)	22.8 (5.9)	<0.01	21.9 (5.5)	23.9 (6.5)	0.22

[*] Data are mean (SD) or proportion (%).

[†] P values were for any difference across all quartiles, obtained by analysis of variance, Kruskal-Wallis test, or chi-square test as appropriate

TABLE 2

Multivariable adjusted odds ratios (95%CIs) of overweight and obesity during follow-up by quartile of protein intake, 1730 men, Chicago Western Electric Study

Protein Type Quartile	Median Intake (%kcal)	Overweight		Obesity	
Total		**Model 1***	**Model 2****	**Model 1***	**Model 2****
Q 1	13.0	1.00	1.00	1.00	1.00
Q 2	14.3	1.34 (1.07, 1.67)	1.35 (1.07, 1.70)	1.61 (0.99, 2.63)	1.76 (1.06, 2.90)
Q 3	15.4	1.69 (1.35, 2.12)	1.65 (1.28, 2.11)	2.15 (1.34, 3.44)	2.18 (1.31, 3.64)
Q 4	17.2	2.33 (1.85, 2.93)	2.10 (1.59, 2.78)	3.57 (2.27, 5.60)	3.27 (1.94, 5.51)
P trend		<0.01	<0.01	<0.01	<0.01
Animal					
Q 1	9.3	1.00	1.00	1.00	1.00
Q 2	10.7	1.34 (1.07, 1.67)	1.38 (1.09, 1.76)	1.70 (1.04, 2.78)	1.85 (1.10, 3.11)
Q 3	12.0	1.41 (1.13, 1.77)	1.50 (1.16, 1.93)	2.33 (1.45, 3.74)	2.71 (1.58, 4.64)
Q 4	13.8	2.03 (1.61, 2.56)	2.09 (1.55, 2.81)	3.94 (2.52, 6.16)	4.62 (2.68, 7.98)
P trend		<0.01	<0.01	<0.01	<0.01
Vegetable					
Q 1	2.9	1.00	1.00	1.00	1.00
Q 2	3.3	1.07 (0.85, 1.33)	1.07 (0.85, 1.36)	0.85 (0.57, 1.25)	0.78 (0.52, 1.17)
Q 3	3.6	1.19 (0.95, 1.51)	1.11 (0.87, 1.42)	1.00 (0.67, 1.48)	0.79 (0.52, 1.19)
Q 4	4.1	1.21 (0.96, 1.51)	1.09 (0.83, 1.43)	0.89 (0.60, 1.32)	0.58 (0.36, 0.95)
P trend		0.33	0.56	0.63	0.053

All models were constructed using generalized estimating equations (GEEs) with logit linkage.

*Model one adjusted for age and energy intake.

**Model two adjusted for covariates in model one plus education, cigarette smoking (yes/no), heavy alcohol intake (yes/no), history of chronic disease or diabetes (yes/no), and carbohydrate and saturated fat intake (% kcal).