The Journal of Nutrition
Nutritional Epidemiology

Higher-Protein Diets Are Associated with Higher HDL Cholesterol and Lower BMI and Waist Circumference in US Adults[1–4]

Stefan M Pasiakos,[5]* Harris R Lieberman,[5] and Victor L Fulgoni III[6,7]

[5]Military Nutrition Division, US Army Research Institute of Environmental Medicine, Natick, MA; [6]Oak Ridge Institute for Science and Education, Oak Ridge, TN; and [7]Nutrition Impact LLC, Battle Creek, MI

Abstract

Background: Protein intake above the RDA attenuates cardiometabolic risk in overweight and obese adults during weight loss. However, the cardiometabolic consequences of consuming higher-protein diets in free-living adults have not been determined.

Objective: This study examined usual protein intake [g/kg body weight (BW)] patterns stratified by weight status and their associations with cardiometabolic risk using data from the NHANES, 2001–2010 (n = 23,876 adults ≥19 y of age).

Methods: Linear and decile trends for association of usual protein intake with cardiometabolic risk factors including blood pressure, glucose, insulin, cholesterol, and triglycerides were determined with use of models that controlled for age, sex, ethnicity, physical activity, poverty-income ratio, energy intake (kcal/d), carbohydrate (g/kg BW) and total fat (g/kg BW) intake, body mass index (BMI), and waist circumference.

Results: Usual protein intake varied across deciles from 0.69 ± 0.004 to 1.51 ± 0.009 g/kg BW (means ± SEs). Usual protein intake was inversely associated with BMI (−0.47 kg/m^2 per decile and −4.54 kg/m^2 per g/kg BW) and waist circumference (−0.53 cm per decile and −2.45 cm per g/kg BW), whereas a positive association was observed between protein intake and HDL cholesterol (0.01 mmol/L per decile and 0.14 mmol/L per g/kg BW, P < 0.00125).

Conclusions: Americans of all body weights typically consume protein in excess of the RDA. Higher-protein diets are associated with lower BMI and waist circumference and higher HDL cholesterol compared to protein intakes at RDA levels. Our data suggest that Americans who consume dietary protein between 1.0 and 1.5 g/kg BW potentially have a lower risk of developing cardiometabolic disease. *J Nutr* 2015;145:605–14.

Keywords: recommended dietary allowance, body mass index, waist circumference, high-density lipoprotein, NHANES

Introduction

Diets that promote protein intake above the RDA [0.8 g/kg body weight (BW)] are extremely popular. Studies have demonstrated that higher-protein diets promote healthy weight management (1, 2) and spare lean body mass during weight loss (3–10). Increasing dietary protein intake at the expense of carbohydrate may also lower cardiometabolic risk (11) because diets higher in protein and lower in carbohydrate appear to reduce blood pressure (12, 13) and improve glycemic regulation (11, 14) and blood lipid profiles (10, 12, 15–17). The cardiometabolic benefits of higher-protein diets are often greater than or equal to those observed when consuming lower-fat, higher-carbohydrate diets consistent with the 2010 Dietary Guidelines for Americans (18) and recommendations of the AHA (19). However, most of the studies reporting benefits of higher-protein diets were conducted in overweight and obese adults during well-controlled weight loss interventions. Whether these findings apply to free-living adults habitually consuming higher-protein diets independent of body size, total energy, and macronutrient intake has not been established.

Despite evidence from clinical trials suggesting that higher-protein diets may lower cardiometabolic risk, concerns exist regarding the potential long-term adverse health effects of habitually consuming high protein diets (20–23), and precisely what level of protein intake results in optimal health remains controversial (24–27). Prospective studies have suggested that consuming

[1] Supported by the US Army Military Research and Materiel Command and the Department of Defense Center Alliance for Dietary Supplements Research.
[2] Author disclosures: SM Pasiakos, HR Lieberman, and VL Fulgoni, no conflicts of interest.
[3] The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Army or the Department of Defense. Any citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement of approval of the products or services of these organizations.
[4] Supplemental Tables 1–4 are 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 http://jn.nutrition.org.
* To whom correspondence should be addressed. E-mail: stefan.pasiakos@us.army.mil.

Manuscript received October 3, 2014. Initial review completed November 11, 2014. Revision accepted December 24, 2014.
First published online January 21, 2015; doi:10.3945/jn.114.205203.

dietary protein at upper levels of the acceptable macronutrient distribution range (10–35% total energy intake) may increase cardiometabolic risk (28) and all-cause mortality (29, 30). Partial data from the NHANES III suggests that cardiometabolic-related mortality is higher in middle-aged adults (50–65 y of age) consuming higher-protein diets compared with similarly aged adults consuming lower-protein diets (20). The authors of that paper recommend that middle-aged adults consume dietary protein at levels consistent with the RDA, although the authors also recommended that older (>65 y of age) adults should increase protein intake above the RDA to increase longevity and lower cardiometabolic-related mortality. Conflicting data and experimental limitations (e.g., sample size, dietary analysis, interventional vs. prospective) within and across studies make it difficult to reconcile these studies leading to confusion among clinicians, the nutrition community, and the lay public regarding the true association between dietary protein and cardiometabolic health.

This study evaluated dietary protein intake patterns among US adults and assessed relations between habitual protein intake and cardiometabolic risk with use of data from the NHANES, 2001–2010. Whether habitual protein intake patterns and their associations with cardiometabolic risk are differentially influenced by BW status was also assessed by stratifying the study population by BMI. We expected that protein intake would exceed the RDA. We hypothesized that higher-protein diets would be associated with biomarkers suggestive of reduced cardiometabolic risk, and that the effects of dietary protein would be more pronounced in overweight and obese adults than in normal weight adults.

Methods

Participants. The study population consisted of 23,876 adults (≥19 y of age) who completed a 24-h dietary recall in "What We Eat in America," the dietary interview component of the NHANES, 2001–2010 (31). Analyses included only individuals with complete and reliable dietary records as determined by the National Center for Health Statistics staff. Pregnant or lactating women were excluded. Underweight individuals (BMI <18.5 kg/m^2) were also excluded (n = 421, 1.76% of population; 164 males and 257 females) because these individuals could have a chronic disease or an eating disorder. Individual usual protein intake (g/kg BW) was determined with use of the National Cancer Institute method (32) with DRI age groups, day of the recall, and a weekend flag (Monday–Thursday vs. Friday–Sunday) as covariates.

All subjects were separated into deciles of individual usual protein intake. The population was then stratified by BW status: normal weight (BMI: 18.5–24.9 kg/m^2; n = 7131), overweight (BMI: 25.0–29.9 kg/m^2; n = 8374), and obese (BMI: >30 kg/m^2; n = 8376). Individual usual protein intake deciles were then determined according to BMI categories. Demographics (age, sex, race/ethnicity) and dietary intake characteristics (energy and macronutrient intake) of the population within deciles of protein intake were determined for the entire population and stratified by BMI categories.

Cardiometabolic risk factors. BMI, waist circumference, blood pressure (diastolic and systolic), fasting serum TGs, total cholesterol, LDL cholesterol, HDL cholesterol, blood glucose, and insulin concentrations were obtained from examination (33) and laboratory files (34). HOMA-IR was calculated as the product of plasma insulin (pmol/L) and glucose (mmol/L)/22.5 (35).

Statistical analysis. Analyses were completed with use of SAS 9.2 (SAS Institute) and SUDAAN release 11.0 (Research Triangle Institute) for sexes combined and separately for each sex. Appropriate weighting factors were used to adjust for oversampling of selected groups, survey nonresponses of some individuals, and for day of the week the interview was conducted (36). Least square means (± SEs) of cardiometabolic risk variables were determined for subjects in each decile of habitual protein intake (g/kg BW) with use of PROC REGRESS of SUDAAN after adjustment for covariates. Three covariate models were employed: model 1—adjusted all variables for sex (combined sexes only), race/ethnicity, age, physical activity (categorized as sedentary, moderate, or vigorous based on responses to questions on activity), and poverty-income ratio; model 2—adjusted all variables for the covariates in model 1 and also for individual usual energy intake (kcal/d); and model 3—where BMI and waist circumference were adjusted for the covariates in model 1 and also individual usual intake of carbohydrates (g/kg BW) and total fat (g/kg BW), whereas the remaining cardiometabolic variables were adjusted for covariates in model 1, individual usual intake of carbohydrates (g/kg BW) and total fat (g/kg BW), and BMI. Analyses were also conducted to determine whether medication use (related to blood pressure, lipids, or insulin management) affected model 3 results.

Both a linear trend of habitual dietary protein intake as a continuous variable and a linear trend across deciles of habitual protein intake were computed with use of the covariate-adjusted models described above. Subjects with missing data for a variable of interest were eliminated from that particular analysis. Significance was set at a Bonferroni-adjusted α of $P < 0.00125$ [$P < 0.05$ divided by 40 (4 weight classification groups and 10 sets of variables analyzed)].

Results

Median habitual protein intake for the entire population more than doubled from decile 1 to decile 10 (**Table 1**). A higher percentage of females consumed protein within deciles 1 through 5, whereas a higher percentage of males consumed protein within deciles 6 through 10 (Table 1). Age decreased across increasing deciles of protein intake. Similar demographic trends were observed when the analyses were stratified by weight status. Energy and macronutrient intake also increased across the deciles for the total population and within weight classifications (**Table 2**).

BMI and waist circumference, for the total population and within weight classifications, were inversely associated with habitual protein intake as a continuous variable and when examined by deciles of habitual protein intake (**Table 3**). Using model 2 (additionally adjusted for energy intake), the relation between habitual protein intake and BMI was significant for deciles of habitual protein intake in the entire population but not when the analyses were stratified by weight classification. Using model 3 (additionally adjusted for other macronutrient intake), habitual protein intake as a continuous variable and deciles of habitual protein intake were associated with BMI in all subjects and for overweight and obese but not normal weight subjects. Using model 2, the relation of habitual protein intake with waist circumference was significant for protein intake as a continuous variable and for deciles of habitual protein intake in all subjects. When the population was stratified by weight classification and adjustments for energy intake were made (model 2), there was a significant association of habitual protein intake in overweight subjects only. Using model 3, habitual protein intake as a continuous variable and deciles of habitual protein intake were associated with waist circumference in all subjects and within each weight classification.

Habitual protein intake was not associated with any other cardiometabolic risk factor after appropriate adjustments for energy and macronutrient intake with the exception of HDL cholesterol (**Table 4**). There was a positive association of habitual protein intake as a continuous variable, and deciles of habitual protein intake, with HDL cholesterol in all subjects and when subjects were stratified by weight classification. Using model 2, the positive relation between habitual protein intake and HDL cholesterol was significant for all subjects, and particularly for overweight individuals. Using model 3 (including adjustment for BMI), both decile and continuous measurement of

TABLE 1 Demographics of US adults according to individual usual protein intake and BW classifications[1]

	Decile of individual usual protein intake									
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
All subjects (*n* = 23,876)										
Sample size, *n*	2775	2689	2537	2351	2377	2315	2187	2210	2180	2255
Median protein intake, g/kg BW	0.69	0.80	0.87	0.93	0.99	1.05	1.12	1.20	1.30	1.51
Female, %	84.5 ± 1.0	76.8 ± 0.9	68.3 ± 1.2	60.6 ± 1.2	55.1 ± 1.4	45.6 ± 1.5	39.7 ± 1.2	31.8 ± 1.5	26.7 ± 1.2	16.7 ± 1.2
Age, y	52.4 ± 0.4	52.8 ± 0.5	51.3 ± 0.6	49.3 ± 0.6	49.1 ± 0.6	46.9 ± 0.4	44.6 ± 0.4	43.0 ± 0.4	39.6 ± 0.4	35.6 ± 0.4
Ethnicity, %										
Hispanic	9.0 ± 1.1	11.1 ± 1.3	10.6 ± 1.2	10.9 ± 1.2	10.1 ± 1.1	11.7 ± 1.2	13.7 ± 1.1	13.3 ± 1.1	14.7 ± 1.3	16.9 ± 1.5
White	68.6 ± 2.1	70.9 ± 1.9	73.2 ± 1.9	72.5 ± 1.8	75.6 ± 1.7	73.5 ± 1.8	72.9 ± 1.7	70.3 ± 1.7	68.4 ± 1.9	68.3 ± 1.9
Black	19.1 ± 1.6	13.3 ± 1.2	12.2 ± 1.3	10.5 ± 1.0	10.3 ± 1.0	9.7 ± 0.8	8.2 ± 0.9	9.9 ± 0.9	9.6 ± 0.8	9.7 ± 0.8
Other	3.3 ± 0.5	4.7 ± 0.7	3.9 ± 0.5	6.1 ± 1.0	4.0 ± 0.6	5.0 ± 0.6	5.2 ± 0.8	6.4 ± 1.0	7.3 ± 1.0	5.2 ± 0.7
Normal weight (*n* = 7131)										
Sample size, *n*	778	744	705	691	704	709	712	695	671	722
Median protein intake, g/kg BW	0.76	0.87	0.94	1.01	1.08	1.14	1.22	1.30	1.43	1.64
Female, %	85.2 ± 1.5	79.8 ± 1.8	72.7 ± 2.2	66.0 ± 2.5	63.9 ± 2.3	60.6 ± 2.7	50.9 ± 2.4	42.1 ± 2.4	27.8 ± 2.8	19.9 ± 2.3
Age, y	51.3 ± 0.8	49.8 ± 0.9	48.8 ± 0.9	46.3 ± 0.9	44.1 ± 0.8	44.0 ± 0.8	41.8 ± 0.8	37.6 ± 0.7	36.3 ± 0.7	33.6 ± 0.7
Ethnicity, %										
Hispanic	7.0 ± 1.0	7.5 ± 1.2	5.9 ± 0.9	8.7 ± 1.2	8.7 ± 1.3	10.7 ± 1.3	11.1 ± 1.2	13.2 ± 1.6	13.0 ± 1.8	15.7 ± 1.9
White	78.1 ± 2.1	75.7 ± 2.3	79.2 ± 2.0	78.0 ± 2.1	74.8 ± 2.4	73.1 ± 2.2	70.1 ± 2.5	70.2 ± 2.6	68.4 ± 2.8	69.1 ± 2.4
Black	10.4 ± 1.1	8.3 ± 1.0	7.2 ± 1.1	7.1 ± 1.0	7.8 ± 1.0	9.0 ± 1.2	8.6 ± 1.2	9.0 ± 1.3	9.2 ± 1.3	9.3 ± 1.0
Other	4.6 ± 1.0	8.5 ± 1.5	7.8 ± 1.5	6.2 ± 1.3	8.7 ± 1.7	7.2 ± 1.3	10.2 ± 2.1	7.6 ± 1.5	9.4 ± 1.8	5.9 ± 1.2
Overweight (*n* = 8371)										
Sample size, *n*	976	951	904	847	797	809	774	789	728	796
Median protein intake, g/kg BW	0.71	0.83	0.90	0.95	1.01	1.06	1.13	1.20	1.30	1.49
Female, %	80.0 ± 1.9	70.5 ± 2.1	64.2 ± 2.1	55.0 ± 2.5	45.7 ± 2.9	34.3 ± 2.2	28.1 ± 2.2	21.5 ± 2.0	15.1 ± 1.9	7.8 ± 1.0
Age, y	54.8 ± 0.7	55.4 ± 0.8	52.7 ± 1.0	51.9 ± 0.8	51.7 ± 0.7	48.6 ± 0.6	45.6 ± 0.6	44.3 ± 0.7	41.8 ± 0.6	36.7 ± 0.6
Ethnicity, %										
Hispanic	11.8 ± 2.0	10.9 ± 1.4	12.7 ± 1.6	12.0 ± 1.5	9.3 ± 1.2	14.4 ± 1.9	17.2 ± 2.1	15.7 ± 1.8	14.8 ± 1.8	18.7 ± 1.8
White	69.4 ± 3.1	74.4 ± 2.4	72.5 ± 2.3	73.6 ± 2.6	76.7 ± 2.1	74.1 ± 2.2	71.2 ± 2.7	69.4 ± 2.3	70.1 ± 2.6	66.0 ± 2.3
Black	14.2 ± 1.7	11.5 ± 1.6	10.6 ± 1.4	9.2 ± 1.1	10.2 ± 1.2	7.8 ± 1.1	7.3 ± 1.0	10.1 ± 1.2	8.9 ± 1.2	10.6 ± 1.4
Other	4.7 ± 1.2	3.2 ± 1.0	4.2 ± 1.1	5.3 ± 1.8	3.9 ± 1.2	3.7 ± 0.9	4.4 ± 1.1	4.9 ± 1.2	6.2 ± 1.2	4.8 ± 1.2
Obese (*n* = 8374)										
Sample size, *n*	992	865	944	897	840	819	810	727	699	781
Median protein intake, g/kg BW	0.64	0.74	0.80	0.85	0.91	0.96	1.02	1.09	1.17	1.33
Female, %	90.0 ± 1.0	80.0 ± 2.1	75.2 ± 2.1	67.1 ± 2.4	58.8 ± 2.5	51.9 ± 2.5	42.5 ± 2.4	34.1 ± 2.5	17.1 ± 1.8	13.3 ± 1.8
Age, y	51.9 ± 0.8	51.6 ± 0.8	52.1 ± 0.8	50.2 ± 0.7	48.1 ± 0.8	47.5 ± 0.9	47.3 ± 0.7	45.0 ± 0.8	41.8 ± 0.6	39.2 ± 0.6
Ethnicity, %										
Hispanic	9.4 ± 1.3	8.7 ± 1.7	11.6 ± 1.3	12.0 ± 1.6	12.9 ± 1.8	13.4 ± 1.7	11.3 ± 1.5	11.8 ± 1.7	16.0 ± 2.0	19.1 ± 2.4
White	62.5 ± 3.0	70.0 ± 2.3	68.8 ± 2.5	69.3 ± 2.6	67.4 ± 2.7	70.6 ± 2.6	73.0 ± 2.2	70.8 ± 2.5	72.7 ± 2.4	65.9 ± 2.7
Black	25.4 ± 2.4	18.2 ± 1.8	16.0 ± 1.8	16.1 ± 2.1	15.4 ± 1.7	13.5 ± 1.7	12.4 ± 1.4	12.5 ± 1.4	9.0 ± 1.1	11.4 ± 1.2
Other	2.8 ± 0.8	3.6 ± 0.9	3.6 ± 0.9	2.7 ± 0.7	4.3 ± 1.0	2.5 ± 0.9	3.3 ± 0.8	5.0 ± 1.1	2.3 ± 0.7	3.6 ± 0.9

[1] Values are least square means ± SEs with the exception of sample size (*n*) and decile median protein intake (g/kg BW). Source: NHANES, 2001–2010. BW, body weight; D, decile.

habitual protein intake were still associated with HDL cholesterol in all subjects and for overweight individuals. Continuous measurements of habitual protein intake were also positively associated with HDL cholesterol in normal weight individuals, but decile of habitual protein intake relation was not significant.

Analyses were also conducted to examine sex-based differences, however, the results were not different from those described above; habitual protein intake was inversely associated with BMI and waist circumference and positively associated with HDL cholesterol to a similar extent in men and women (**Supplemental Tables 1–4**). No other associations were observed when analyzing the data by sex. Finally, including relevant medication use in models where appropriate did not alter the associations between dietary protein and cardiometabolic risk (data not shown).

Discussion

The major findings from this prospective, cross-sectional study are the following: *1*) Americans habitually consume protein in excess of the RDA; and *2*) higher-protein diets are associated with lower BMI, waist circumference, and higher HDL cholesterol. The potential health effects of higher-protein diets appear to be more pronounced in overweight individuals (BMI: 25.0–29.9 kg/m^2) than in normal weight (BMI: 18.5–24.9 kg/m^2) and obese individuals (BMI: >30 kg/m^2). These findings are consistent with previous studies (10–17) and suggest that the cardiometabolic advantages of higher-protein diets are largely independent of energy, carbohydrate, and fat intake, but appear limited to HDL cholesterol, waist circumference, and BMI.

The RDA (0.8 g/kg BW) represents a minimum level of protein consumption required to avoid a deficiency that would

TABLE 2 Energy and macronutrient intake according to individual usual protein intake and BW classifications in US adults[1]

	Decile of individual usual protein intake									
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
All subjects (*n* = 23,876)										
Sample size, *n*	2775	2689	2537	2351	2377	2315	2187	2210	2180	2255
Median protein intake, g/kg BW	0.69	0.80	0.87	0.93	0.99	1.05	1.12	1.20	1.30	1.51
Energy intake, kcal/d	1119 ± 13	1469 ± 14	1679 ± 17	1823 ± 19	1995 ± 20	2163 ± 15	2348 ± 22	2576 ± 24	2886 ± 22	3743 ± 46
Protein, g/d	31.8 ± 0.4	48.4 ± 0.3	57.3 ± 0.5	64.4 ± 0.6	73.3 ± 0.5	81.6 ± 0.5	90.3 ± 0.6	102.8 ± 0.8	117.8 ± 0.8	165.0 ± 1.4
Protein, % energy	12.1 ± 0.1	14.2 ± 0.1	14.4 ± 0.1	15.0 ± 0.1	15.6 ± 0.1	16.0 ± 0.1	16.3 ± 0.1	17.0 ± 0.2	17.2 ± 0.1	18.6 ± 0.2
Carbohydrates, g/d	160.5 ± 1.9	194.5 ± 2.3	215.6 ± 2.9	230.1 ± 2.7	246.2 ± 3.1	263.9 ± 2.9	282.9 ± 3.2	303.9 ± 3.3	334.0 ± 3.6	414.2 ± 6.6
Carbohydrates, % energy	57.3 ± 0.3	52.5 ± 0.3	51.1 ± 0.3	50.1 ± 0.4	49.3 ± 0.4	48.4 ± 0.4	48.0 ± 0.3	46.8 ± 0.3	46.0 ± 0.4	43.9 ± 0.3
Total fat, g/d	38.6 ± 0.7	54.1 ± 0.7	62.6 ± 0.8	67.6 ± 1.1	75.1 ± 1.0	82.3 ± 0.9	88.9 ± 1.1	97.4 ± 1.2	111.0 ± 1.3	146.1 ± 2.3
Total fat, % energy	30.5 ± 0.3	32.9 ± 0.3	33.3 ± 0.3	33.2 ± 0.3	33.5 ± 0.3	34.1 ± 0.3	33.8 ± 0.3	34.0 ± 0.3	34.4 ± 0.3	34.8 ± 0.3
Normal weight (*n* = 7131)										
Sample size, *n*	778	744	705	691	704	709	712	695	671	722
Median protein intake, g/kg BW	0.76	0.87	0.94	1.01	1.08	1.14	1.22	1.30	1.43	1.64
Energy intake, kcal/d	1115 ± 21	1419 ± 22	1647 ± 31	1773 ± 29	1929 ± 24	2169 ± 33	2336 ± 37	2583 ± 33	2996 ± 54	3903 ± 79
Protein, g/d	28.8 ± 0.5	44.2 ± 0.3	52.6 ± 0.5	61.6 ± 0.4	69.3 ± 0.6	79.1 ± 0.6	88.8 ± 0.7	99.8 ± 0.6	122.5 ± 0.8	170.8 ± 2.5
Protein, % energy	11.2 ± 0.2	13.4 ± 0.2	13.8 ± 0.2	14.8 ± 0.2	15.3 ± 0.2	15.6 ± 0.2	16.2 ± 0.3	16.4 ± 0.2	17.4 ± 0.3	18.5 ± 0.3
Carbohydrates, g/d	162.0 ± 3.0	191.2 ± 4.2	217.0 ± 4.7	227.2 ± 4.3	241.4 ± 4.7	269.3 ± 4.3	287.2 ± 5.3	318.0 ± 5.8	353.2 ± 9.0	441.3 ± 11.3
Carbohydrates, % energy	58.5 ± 0.7	53.3 ± 0.6	52.3 ± 0.6	51.2 ± 0.6	49.5 ± 0.7	49.6 ± 0.4	48.8 ± 0.5	48.8 ± 0.5	46.5 ± 0.6	44.6 ± 0.5
Total fat, g/d	36.2 ± 1.1	50.7 ± 1.0	57.9 ± 1.3	63.6 ± 1.4	71.5 ± 1.3	79.7 ± 1.8	86.2 ± 2.2	94.4 ± 1.9	111.8 ± 2.3	150.5 ± 3.4
Total fat, % energy	29.0 ± 0.6	32.3 ± 0.5	31.7 ± 0.5	32.2 ± 0.4	33.4 ± 0.5	32.7 ± 0.3	33.2 ± 0.5	32.7 ± 0.4	33.5 ± 0.4	34.5 ± 0.4
Overweight (*n* = 8371)										
Sample size, *n*	976	951	904	847	797	809	774	789	728	796
Median protein intake, g/kg BW	0.71	0.83	0.90	0.95	1.01	1.06	1.13	1.20	1.30	1.49
Energy intake, kcal/d	1054 ± 165	1501 ± 20	1669 ± 16	1831 ± 25	2044 ± 28	2183 ± 28	2375 ± 36	2653 ± 33	2967 ± 39	3836 ± 54
Protein, g/d	29.3 ± 0.4	47.5 ± 0.3	57.2 ± 0.3	64.7 ± 0.5	73.4 ± 0.5	81.0 ± 0.5	90.6 ± 0.7	104.0 ± 0.7	122.4 ± 1.0	171.7 ± 1.9
Protein, % energy	12.0 ± 0.2	13.8 ± 0.2	14.5 ± 0.2	15.3 ± 0.2	15.3 ± 0.2	15.8 ± 0.3	16.2 ± 0.2	16.7 ± 0.2	17.5 ± 0.2	18.9 ± 0.3
Carbohydrates, % energy	57.2 ± 0.6	52.5 ± 0.6	51.0 ± 0.4	50.7 ± 0.6	49.6 ± 0.7	49.0 ± 0.5	47.6 ± 0.5	46.9 ± 0.5	44.8 ± 0.6	43.0 ± 0.6
Total fat, g/d	36.2 ± 0.8	54.5 ± 1.0	62.3 ± 0.9	65.7 ± 1.5	75.2 ± 1.4	81.1 ± 1.5	89.6 ± 1.9	99.4 ± 1.7	116.0 ± 2.2	150.7 ± 3.1
Total fat, % energy	30.5 ± 0.5	32.6 ± 0.4	33.4 ± 0.4	32.1 ± 0.5	33.1 ± 0.5	33.4 ± 0.4	33.8 ± 0.4	33.6 ± 0.4	35.1 ± 0.5	35.1 ± 0.5
Obese (*n* = 8374)										
Sample size, *n*	992	865	944	897	840	819	810	727	699	781
Median protein intake, g/kg BW	0.64	0.74	0.80	0.85	0.91	0.96	1.02	1.09	1.17	1.33
Energy intake, kcal/d	1088 ± 22.3	1394 ± 22	1604 ± 25	1808 ± 25	1980 ± 28	2114 ± 31	2326 ± 28	2586 ± 37	2847 ± 47	3673 ± 59
Protein, g/d	30.3 ± 0.6	46.6 ± 0.6	56.3 ± 0.6	64.7 ± 0.6	73.5 ± 0.8	82.3 ± 0.9	93.1 ± 0.8	104.3 ± 0.9	119.3 ± 1.1	167.3 ± 2.3
Protein, % energy	12.0 ± 0.2	14.4 ± 0.2	15.1 ± 0.2	15.2 ± 0.2	15.8 ± 0.2	16.4 ± 0.3	17.0 ± 0.3	17.0 ± 0.2	17.8 ± 0.3	19.2 ± 0.3
Carbohydrates, g/d	160.0 ± 3.9	185.6 ± 4.0	206.0 ± 3.6	226.6 ± 4.4	243.3 ± 4.7	250.6 ± 4.9	273.4 ± 5.1	303.6 ± 7.0	320.1 ± 7.1	384.9 ± 8.9
Carbohydrates, % energy	58.4 ± 0.6	52.3 ± 0.5	50.8 ± 0.5	49.7 ± 0.5	48.5 ± 0.5	47.0 ± 0.6	46.6 ± 0.5	46.3 ± 0.6	44.3 ± 0.5	41.4 ± 0.6
Total fat, g/d	36.5 ± 1.0	52.0 ± 1.1	61.3 ± 1.4	69.5 ± 1.3	77.0 ± 1.4	84.3 ± 1.8	91.7 ± 1.5	100.8 ± 1.9	112.2 ± 2.6	150.6 ± 3.1
Total fat, % energy	30.0 ± 0.6	33.6 ± 0.5	34.0 ± 0.4	34.4 ± 0.5	34.9 ± 0.5	35.6 ± 0.5	35.2 ± 0.4	35.0 ± 0.5	35.6 ± 0.6	36.7 ± 0.5

[1] Values are least square means ± SEs with the exception of sample size (*n*) and decile median protein intake (g/kg BW). Source: NHANES, 2001–2010. BW, body weight; D, decile.

lead to a progressive loss of muscle mass in healthy adults, as reflected by negative nitrogen balance (37). However, numerous studies demonstrate advantages of consuming protein in excess of the RDA for skeletal muscle mass (1, 2, 38–42). Our findings suggest that habitual dietary protein intake may also serve as a nutritional determinant of adiposity (15). More specifically, waist circumference and BMI were inversely associated with protein intake, suggesting that central adiposity was lower for Americans consuming higher-protein diets. The association between waist circumference and dietary protein was present in each BMI classification, although the effects of protein on BMI appear to be largely restricted to overweight adults. These findings are consistent with a recent meta-analysis demonstrating a small, but highly significant, inverse association of dietary protein intake with fat mass in overweight and obese individuals adhering to higher-protein, ad libitum diets after completing a controlled weight loss intervention (43).

It should be noted that our analyses did not show any detrimental association between dietary protein and cardiometabolic risk. Increased dietary protein intake at the expense of carbohydrate is generally considered to reduce cardiometabolic risk because studies have consistently reported improvements in glycemic regulation (11, 14), blood lipids (10, 12, 15–17), and blood pressure (12, 13) in overweight and obese adults adhering to controlled higher-protein, lower-carbohydrate weight loss diets. Our data suggest that the cardiometabolic advantages of habitual higher-protein diets in free-living adults are limited to increases in HDL cholesterol. Because we adjusted for multiple physiological confounders, the robust association between dietary protein and HDL cholesterol is particularly intriguing. More specifically, HDL cholesterol concentrations for those who consumed ~1.5 g protein/kg BW were ~15% higher than those who consumed protein at or below the RDA, particularly in overweight individuals. The mechanism by which protein is

TABLE 3 Association of individual usual protein intake with BMI and waist circumference in US adults[1]

	Decile of individual usual protein intake, g/kg BW			Decile trend		Linear trend	
	D1	D5	D10	β	P^2	β	P^2
BMI, kg/m^2							
Model 1							
All	33.4 ± 0.3	28.8 ± 0.2	24.3 ± 0.1	−0.887	<0.0001	−9.686	<0.0001
Normal weight	22.8 ± 0.1	22.3 ± 0.1	21.8 ± 0.1	−0.080	<0.0001	−0.890	<0.0001
Overweight	27.6 ± 0.1	27.4 ± 0.1	27.1 ± 0.1	−0.061	<0.0001	−0.700	<0.0001
Obese	38.7 ± 0.4	35.8 ± 0.3	33.3 ± 0.2	−0.499	<0.0001	−6.423	<0.0001
Model 2							
All	29.9 ± 0.3	28.3 ± 0.2	28.8 ± 0.2	−0.193	<0.0001	−0.225	0.54
Normal weight	22.3 ± 0.1	22.3 ± 0.1	22.4 ± 0.1	0.014	0.36	0.245	0.15
Overweight	27.4 ± 0.1	27.4 ± 0.1	27.4 ± 0.1	−0.018	0.15	−0.089	0.57
Obese	36.8 ± 0.4	35.6 ± 0.3	35.6 ± 0.3	−0.104	0.04	−0.277	0.71
Model 3							
All	31.4 ± 0.3	28.6 ± 0.2	26.9 ± 0.2	−0.471	<0.0001	−4.544	<0.0001
Normal weight	22.5 ± 0.1	22.3 ± 0.1	22.2 ± 0.1	−0.012	0.41	−0.125	0.44
Overweight	27.5 ± 0.1	27.4 ± 0.1	27.2 ± 0.1	−0.045	0.0001	−0.514	0.0002
Obese	37.7 ± 0.4	35.7 ± 0.3	34.4 ± 0.3	−0.289	<0.0001	−3.485	<0.0001
Waist circumference, cm							
Model 1							
All	108.1 ± 0.6	98.8 ± 0.4	86.6 ± 0.3	−2.108	<0.0001	−23.289	<0.0001
Normal weight	83.8 ± 0.4	82.8 ± 0.4	80.1 ± 0.3	−0.352	<0.0001	−3.708	<0.0001
Overweight	97.6 ± 0.3	96.8 ± 0.3	94.4 ± 0.3	−0.368	<0.0001	−4.206	<0.0001
Obese	118.9 ± 0.9	114.8 ± 0.6	107.8 ± 0.5	−1.052	<0.0001	−14.202	<0.0001
Model 2							
All	100.4 ± 0.5	97.6 ± 0.4	96.5 ± 0.5	−0.526	<0.0001	−2.447	0.0020
Normal weight	82.9 ± 0.4	82.6 ± 0.4	81.3 ± 0.4	−0.132	0.02	−1.224	0.07
Overweight	96.8 ± 0.4	96.7 ± 0.3	95.3 ± 0.4	−0.225	0.0005	−2.335	0.00
Obese	115.0 ± 0.9	114.31 ± 0.6	112.6 ± 0.7	−0.230	0.03	−2.448	0.10
Model 3							
All	103.8 ± 0.5	98.1 ± 0.4	92.2 ± 0.4	−1.195	<0.0001	−12.639	<0.0001
Normal weight	83.3 ± 0.4	82.6 ± 0.4	80.8 ± 0.4	−0.217	0.0003	−2.361	0.0004
Overweight	97.4 ± 0.3	96.9 ± 0.3	94.5 ± 0.4	−0.353	<0.0001	−4.320	<0.0001
Obese	117.04 ± 1.0	114.6 ± 0.6	110.0 ± 0.7	−0.639	<0.0001	−9.303	<0.0001

[1] Values are least square means ± SEs. ANOVA was conducted with the following covariate models: model 1—adjusted for age, sex, ethnicity, physical activity, and poverty-income ratio; model 2—adjusted for age, sex, ethnicity, physical activity, poverty-income ratio, and individual usual energy intake (kcal/d); and model 3—adjusted for age, sex, ethnicity, physical activity, poverty-income ratio, carbohydrates (g/kg), and total fat (g/kg). Source: NHANES, 2001–2010. Sample sizes—All: decile 1 (n = 2775), decile 5 (n = 2377), and decile 10 (n = 2255); Normal: decile 1 (n = 778), decile 5 (n = 704), and decile 10 (n = 722); Overweight: decile 1 (n = 976), decile 5 (n = 797), and decile 10 (n = 796); and Obese: decile 1 (n = 992), decile 5 (n = 840), and decile 10 (n = 781). D, decile.

[2] Indicates significant decile and linear trend with a Bonferroni-corrected P value of <0.00125 (0.05/40).

associated with upregulated HDL cholesterol production and the extent to which BW status modulates this response requires further study. Nevertheless, because habitually consuming a higher-protein diet was associated with higher HDL cholesterol (and lower adiposity) regardless of total dietary energy, carbohydrate, and fat intake, the intrinsic properties of protein, unrelated to its energy content, appear to be partially responsible for these effects.

This study demonstrates the health-related benefits associated with habitual consumption of dietary protein beyond the RDA. The levels of protein routinely consumed in deciles 6 through 10 (~1.0–1.5 g/kg BW), that were associated with lower waist circumference, BMI, and higher HDL cholesterol, are consistent with nationally recognized recommendations (i.e., based on nitrogen and skeletal muscle retention) for physically active adults (42, 44), military personnel (45, 46), older adults (47), and for individuals attempting weight loss (9, 10, 48, 49), all of which are higher than the current RDA. Regardless of recommendations, Americans overwhelmingly consume protein at or above the RDA. A previous analysis of the NHANES (2003–2004) showed that the proportion of population reporting consuming protein below the RDA was minimal and that mean protein intake for adults >18 y of age was ~1.3 g/kg ideal BW (50). Our current study, which examined patterns of dietary protein intake across BMI classifications in a much larger sample and controlled for the potential confounders of energy, fat, and carbohydrate intake, confirms the previous report that Americans are rarely protein deficient (less than the estimated average requirement or RDA). Many consumed protein at levels consistent with the RDA (typically women and older adults) and more than half reported consuming protein exceeding 1.0 g/kg BW. We also found that protein intake did not exceed ~19% of total energy intake regardless of the absolute and relative amount of protein in the diet, suggesting that the upper-end of the acceptable macronutrient distribution range for protein (35%) is difficult to achieve, and that protein intake was not influenced by BW status.

This population-based study provides a novel examination of habitual dietary protein intake patterns and their associations

TABLE 4 Association of individual usual protein intake with cardiometabolic risk in US adults[1]

	Decile of individual usual protein intake, g/kg BW			Decile trend		Linear trend	
	D1	D5	D10	β	P^2	β	P
Diastolic blood pressure, mm Hg							
Model 1							
All	71.9 ± 0.4	71.1 ± 0.4	69.7 ± 0.5	−0.122	0.00	−1.854	<0.0001
Normal weight	68.7 ± 0.7	68.6 ± 0.5	68.7 ± 0.6	0.045	0.58	0.237	0.77
Overweight	71.7 ± 0.5	71.16 ± 0.3	71.1 ± 0.7	0.007	0.93	−0.189	0.82
Obese	72.5 ± 0.6	72.8 ± 0.5	73.9 ± 0.7	0.122	0.11	1.676	0.11
Model 2							
All	71.6 ± 0.4	71.0 ± 0.4	70.0 ± 0.6	0.022	0.74	−1.414	0.07
Normal weight	69.1 ± 0.8	68.7 ± 0.5	68.2 ± 0.8	−0.002	0.99	−0.705	0.54
Overweight	72.4 ± 0.5	71.3 ± 0.6	70.2 ± 0.8	−0.092	0.39	−2.201	0.12
Obese	73.5 ± 0.7	72.9 ± 0.5	72.7 ± 0.8	−0.066	0.55	−1.483	0.38
Model 3							
All	72.1 ± 0.4	71.1 ± 0.4	69.4 ± 0.6	−0.020	0.75	−1.785	0.01
Normal weight	69.0 ± 0.8	68.6 ± 0.5	68.3 ± 0.8	0.003	0.98	−0.550	0.60
Overweight	72.5 ± 0.6	71.3 ± 0.6	70.0 ± 0.8	−0.125	0.21	−2.584	0.04
Obese	73.8 ± 0.6	72.9 ± 0.5	72.4 ± 0.8	−0.091	0.41	−1.773	0.29
Systolic blood pressure, mm Hg							
Model 1							
All	123.6 ± 0.5	122.2 ± 0.5	122.2 ± 0.5	−0.204	0.00	−1.720	0.02
Normal weight	118.2 ± 1.0	117.7 ± 0.7	119.6 ± 1.0	0.050	0.69	1.015	0.43
Overweight	124.7 ± 0.8	123.2 ± 1.0	124.8 ± 0.5	−0.043	0.65	−0.141	0.89
Obese	125.2 ± 0.8	125.8 ± 0.8	126.8 ± 0.8	0.054	0.61	2.130	0.14
Model 2							
All	123.6 ± 0.5	122.2 ± 0.5	122.2 ± 0.5	−0.160	0.05	−1.406	0.14
Normal weight	119.1 ± 1.1	117.8 ± 0.7	118.4 ± 1.2	−0.168	0.32	−1.309	0.51
Overweight	125.7 ± 0.9	123.4 ± 1.0	123.6 ± 0.8	−0.259	0.06	−3.185	0.07
Obese	125.9 ± 1.0	125.9 ± 0.8	126.0 ± 1.0	−0.099	0.50	1.328	0.55
Model 3							
All	123.2 ± 0.5	122.2 ± 0.5	122.6 ± 0.5	−0.002	0.98	0.934	0.32
Normal weight	118.2 ± 1.1	117.7 ± 0.7	119.5 ± 1.1	0.013	0.93	1.119	0.55
Overweight	125.0 ± 0.9	123.9 ± 1.0	124.5 ± 0.8	−0.115	0.36	−0.970	0.54
Obese	125.2 ± 1.0	125.8 ± 0.8	126.8 ± 1.0	0.087	0.56	4.046	0.07
Glucose, mmol/L							
Model 1							
All	5.85 ± 0.05	5.74 ± 0.05	5.59 ± 0.05	−0.453	0.0003	−5.865	<0.0001
Normal weight	5.35 ± 0.05	5.30 ± 0.05	5.33 ± 0.08	−0.027	0.84	−0.827	0.54
Overweight	5.63 ± 0.07	5.72 ± 0.08	5.86 ± 0.11	0.143	0.59	2.630	0.32
Obese	6.07 ± 0.10	6.08 ± 0.11	5.92 ± 0.10	0.213	0.48	0.641	0.87
Model 2							
All	5.60 ± 0.06	5.70 ± 0.97	5.91 ± 0.06	0.586	0.00	6.195	0.00
Normal weight	5.31 ± 0.06	5.29 ± 0.05	5.39 ± 0.10	0.132	0.49	0.595	0.78
Overweight	5.58 ± 0.09	5.72 ± 0.09	5.92 ± 0.14	0.263	0.47	5.648	0.17
Obese	5.80 ± 0.14	6.05 ± 0.12	6.23 ± 0.13	1.343	0.00	16.320	0.01
Model 3							
All	5.74 ± 0.05	5.72 ± 0.05	5.71 ± 0.05	0.298	0.06	1.986	0.26
Normal weight	5.36 ± 0.06	5.30 ± 0.05	5.32 ± 0.09	−0.044	0.79	−1.635	0.40
Overweight	5.67 ± 0.09	5.74 ± 0.09	5.81 ± 0.13	0.006	0.99	1.279	0.73
Obese	5.95 ± 0.13	6.07 ± 0.12	6.03 ± 0.12	0.897	0.01	9.345	0.08
HOMA-IR							
Model 1							
All	3.93 ± 0.11	3.21 ± 0.1	2.24 ± 0.13	−0.173	<0.0001	−2.066	<0.0001
Normal weight	1.67 ± 0.08	1.63 ± 0.08	1.43 ± 0.06	−0.017	0.04	−0.248	0.00
Overweight	2.62 ± 0.12	2.72 ± 0.13	2.82 ± 0.17	−0.014	0.56	−0.028	0.92
Obese	5.19 ± 0.25	5.06 ± 0.32	5.14 ± 0.48	0.001	0.98	0.044	0.95

(Continued)

TABLE 4 *Continued*

	Decile of individual usual protein intake, g/kg BW			Decile trend		Linear trend	
	D1	D5	D10	β	P^2	β	P
Model 2							
All	2.85 ± 0.14	3.04 ± 0.1	3.6 ± 0.2	0.042	0.00	0.810	0.01
Normal weight	1.52 ± 0.1	1.61 ± 0.08	1.64 ± 0.1	0.017	0.35	0.107	0.61
Overweight	2.58 ± 0.17	2.72 ± 0.13	2.88 ± 0.23	−0.012	0.87	0.219	0.60
Obese	4.35 ± 0.3	4.96 ± 0.33	6.11 ± 0.64	0.169	0.01	2.916	0.01
Model 3							
All	3.36 ± 0.13	3.12 ± 0.1	2.92 ± 0.17	−0.058	0.02	0.434	0.10
Normal weight	1.62 ± 0.09	1.63 ± 0.08	1.5 ± 0.08	−0.003	0.92	−0.127	0.43
Overweight	2.71 ± 0.16	2.74 ± 0.13	2.72 ± 0.22	−0.037	0.49	−0.043	0.92
Obese	4.77 ± 0.27	5.02 ± 0.32	5.58 ± 0.55	0.085	0.01	2.233	0.01
Insulin, pmol/L							
Model 1							
All	101.74 ± 2.64	84.17 ± 2.29	58.55 ± 2.85	−0.615	<0.0001	−7.244	<0.0001
Normal weight	47.43 ± 1.94	47.50 ± 2.50	41.81 ± 1.67	−0.067	0.03	−0.899	0.00
Overweight	70.42 ± 2.71	73.69 ± 3.26	73.06 ± 3.47	−0.047	0.47	−0.139	0.87
Obese	130.22 ± 5.76	127.72 ± 7.64	126.75 ± 8.89	−0.081	0.54	−0.829	0.65
Model 2							
All	78.62 ± 3.19	80.42 ± 2.22	87.78 ± 4.65	0.195	0.01	1.725	0.06
Normal weight	44.03 ± 2.36	46.95 ± 2.57	46.53 ± 2.57	0.043	0.42	0.263	0.68
Overweight	70.14 ± 3.82	73.62 ± 3.33	73.34 ± 4.31	−0.029	0.72	0.420	0.73
Obese	115.77 ± 6.53	125.98 ± 7.78	143.41 ± 11.81	0.383	0.05	6.307	0.06
Model 3							
All	89.94 ± 3.06	82.3 ± 2.22	72.71 ± 3.75	0.123	0.09	0.676	0.40
Normal weight	46.6 ± 2.15	47.36 ± 2.57	43.06 ± 2.22	−0.025	0.59	−0.626	0.23
Overweight	72.78 ± 3.61	74.03 ± 3.26	70.28 ± 4.31	−0.068	0.42	−0.222	0.86
Obese	123.27 ± 6.18	127.09 ± 7.71	134.11 ± 9.79	0.321	0.04	5.020	0.04
LDL cholesterol, mmol/L							
Model 1							
All	3.07 ± 0.04	3.02 ± 0.03	3.03 ± 0.04	−0.164	0.36	−3.257	0.13
Normal weight	2.91 ± 0.08	2.77 ± 0.06	2.91 ± 0.09	0.332	0.28	0.850	0.79
Overweight	3.26 ± 0.06	3.18 ± 0.07	3.21 ± 0.06	−0.050	0.87	0.060	0.99
Obese	3.03 ± 0.06	3.13 ± 0.07	3.1 ± 0.06	0.545	0.07	6.206	0.14
Model 2							
All	2.96 ± 0.05	3 ± 0.03	3.17 ± 0.06	0.682	0.02	6.388	0.07
Normal weight	2.78 ± 0.09	2.75 ± 0.06	3.09 ± 0.11	1.316	0.00	11.287	0.03
Overweight	3.23 ± 0.07	3.17 ± 0.07	3.24 ± 0.08	0.181	0.71	4.136	0.46
Obese	3.07 ± 0.07	3.13 ± 0.07	3.06 ± 0.09	0.327	0.49	2.053	0.77
Model 3							
All	3.03 ± 0.05	3.01 ± 0.03	3.08 ± 0.05	0.247	0.34	0.126	0.97
Normal weight	2.88 ± 0.09	2.77 ± 0.06	2.95 ± 0.1	0.621	0.13	2.366	0.60
Overweight	3.26 ± 0.07	3.18 ± 0.07	3.21 ± 0.08	0.045	0.93	1.770	0.74
Obese	3.09 ± 0.07	3.13 ± 0.07	3.04 ± 0.08	0.113	0.79	−0.986	0.87
HDL cholesterol, mmol/L							
Model 1							
All	1.23 ± 0.01	1.35 ± 0.01	1.5 ± 0.01	0.995	<0.0001	11.406	<0.0001
Normal weight	1.49 ± 0.02	1.53 ± 0.02	1.59 ± 0.02	0.367	0.0009	3.914	0.0003
Overweight	1.29 ± 0.02	1.32 ± 0.02	1.42 ± 0.02	0.468	<0.0001	5.834	<0.0001
Obese	1.16 ± 0.02	1.2 ± 0.02	1.25 ± 0.02	0.292	0.00	4.073	0.00
Model 2							
All	1.3 ± 0.02	1.36 ± 0.01	1.41 ± 0.02	0.249	0.00	4.049	0.0004
Normal weight	1.5 ± 0.02	1.53 ± 0.02	1.56 ± 0.02	0.266	0.08	3.283	0.06
Overweight	1.3 ± 0.03	1.32 ± 0.02	1.41 ± 0.02	0.378	0.0008	5.716	0.0001
Obese	1.17 ± 0.02	1.2 ± 0.02	1.24 ± 0.02	0.202	0.12	3.589	0.05

(Continued)

TABLE 4 *Continued*

	Decile of individual usual protein intake, g/kg BW			Decile trend		Linear trend	
	D1	D5	D10	β	P^2	β	P
Model 3							
All	1.26 ± 0.02	1.36 ± 0.01	1.46 ± 0.01	0.346	<0.0001	5.420	<0.0001
Normal weight	1.49 ± 0.03	1.53 ± 0.02	1.59 ± 0.02	0.367	0.02	4.627	0.01
Overweight	1.29 ± 0.02	1.32 ± 0.02	1.43 ± 0.02	0.426	0.0001	6.183	<0.0001
Obese	1.16 ± 0.02	1.2 ± 0.02	1.25 ± 0.02	0.222	0.07	3.765	0.03
TGs, mmol/L							
Model 1							
All	1.67 ± 0.04	1.6 ± 0.04	1.35 ± 0.05	−2.283	0.0003	−32.200	<0.0001
Normal weight	1.19 ± 0.04	1.24 ± 0.06	1.13 ± 0.05	−1.264	0.11	−11.727	0.09
Overweight	1.73 ± 0.05	1.62 ± 0.07	1.55 ± 0.1	−0.074	0.93	−5.131	0.67
Obese	1.79 ± 0.1	1.91 ± 0.13	1.96 ± 0.1	2.560	0.06	26.830	0.15
Model 2							
All	1.61 ± 0.06	1.6 ± 0.05	1.42 ± 0.07	−0.285	0.79	−22.868	0.11
Normal weight	1.28 ± 0.08	1.25 ± 0.06	1.01 ± 0.12	−2.836	0.18	−33.060	0.17
Overweight	1.82 ± 0.07	1.64 ± 0.07	1.44 ± 0.11	−0.781	0.46	−23.148	0.17
Obese	1.88 ± 0.14	1.92 ± 0.13	1.86 ± 0.15	1.327	0.52	−1.177	0.97
Model 3							
All	1.56 ± 0.05	1.59 ± 0.04	1.48 ± 0.06	1.291	0.15	2.520	0.83
Normal weight	1.14 ± 0.04	1.23 ± 0.06	1.2 ± 0.11	−0.404	0.76	−0.244	0.99
Overweight	1.75 ± 0.08	1.62 ± 0.07	1.53 ± 0.14	0.583	0.51	−0.171	0.99
Obese	1.76 ± 0.14	1.9 ± 0.14	2.01 ± 0	3.418	0.10	33.820	0.29

[1] Data are least square means ± SEs. ANOVA was conducted with the following covariate models: model 1—adjusted for age, sex, ethnicity, physical activity, and poverty-income ratio; model 2—adjusted for age, sex, ethnicity, physical activity, poverty-income ratio, and individual usual energy intake (kcal/d); and model 3—adjusted for age, sex, ethnicity, physical activity, poverty-income ratio, carbohydrates (g/kg), and total fat (g/kg). Source: NHANES, 2001–2010. Sample sizes—All: decile 1 (n = 2775), decile 5 (n = 2377), and decile 10 (n = 2255); Normal: decile 1 (n = 778), decile 5 (n = 704), and decile 10 (n = 722); Overweight: decile 1 (n = 976), decile 5 (n = 797), and decile 10 (n = 796); and Obese: decile 1 (n = 992), decile 5 (n = 840), and decile 10 (n = 781). BW, body weight; D, decile.
[2] Indicates significant decile and linear trend with a Bonferroni-corrected P value of <0.00125 (0.05/40).

with cardiometabolic risk. The large sample size (~24,000), and our assessments of usual dietary protein intake and cardiometabolic health according to weight classifications, are strengths of the current report. Although our findings suggest that increasing dietary protein intake lowers cardiometabolic risk, there are limitations that warrant consideration when interpreting outcomes from a cross-sectional study. Relying solely on correlative data to evaluate cardiometabolic risk and 24-h recalls to characterize dietary habits can be problematic and lead to misinterpretations of the data with possible over- and underestimations of dietary intake (51). However, the inherent variability with self-report dietary intake data is addressed in part by using the National Cancer Institute method to estimate long-term dietary patterns.

As a biological measure to support the validity of the usual dietary intake data we derived from the NHANES, we examined the association of blood urea nitrogen (BUN) and BUN/creatinine ratio with deciles of usual protein intake in grams/kilograms. BUN is the final product of body protein metabolism. We found highly significant (P < 0.0001) increases in concentrations of BUN and BUN/creatinine ratio because usual protein intake increased across deciles in analysis of sexes combined and separate analyses of males and females, even after adjusting for the covariates used in this study (data not shown). Although these variables may be considered a crude measurement of nitrogen metabolism, they demonstrate that usual protein intake measurements from NHANES data are strongly associated with biochemical measures of protein metabolism. It should be recognized that the biological mechanisms responsible for our findings are not fully understood and there are limitations inherent with the study design we used. However, we applied multiple biologically relevant covariates in our regression analyses to avoid confounding, although there is still a possibility that our results are due to residual effects of variables that we did not control.

In conclusion, our analyses confirm that Americans typically consume protein at levels that exceed the RDA, and their intake is consistent with recommendations to optimize skeletal muscle health regardless of BW status and energy, carbohydrate, and fat intake. Increasing dietary protein intake was associated with reduced cardiometabolic risk, a benefit that may be more pronounced in overweight individuals. Individuals consuming higher-protein diets had a lower BMI and waist circumference and higher HDL cholesterol concentrations compared with individuals consuming protein at levels consistent with the RDA. The cardiometabolic advantages associated with higher-protein diets were largely independent of total energy, carbohydrate, and fat intake. Although our study was cross-sectional, our findings strongly suggest that consuming protein well above the RDA (1.0–1.5 g/kg BW) is safe and may be considered a valid nutritional strategy to improve cardiometabolic health.

Acknowledgments

SMP, HRL, and VLF analyzed the data and wrote the paper. All authors read and approved the final manuscript.

References

1. Westerterp-Plantenga MS, Nieuwenhuizen A, Tome D, Soenen S, Westerterp KR. Dietary protein, weight loss, and weight maintenance. Annu Rev Nutr 2009;29:21–41.

2. Paddon-Jones D, Westman E, Mattes RD, Wolfe RR, Astrup A, Westerterp-Plantenga M. Protein, weight management, and satiety. Am J Clin Nutr 2008;87:1558S–61S.
3. Wycherley TP, Moran LJ, Clifton PM, Noakes M, Brinkworth GD. Effects of energy-restricted high-protein, low-fat compared with standard-protein, low-fat diets: a meta-analysis of randomized controlled trials. Am J Clin Nutr 2012;96:1281–98.
4. Wycherley TP, Brinkworth GD, Clifton PM, Noakes M. Comparison of the effects of 52 weeks weight loss with either a high-protein or high-carbohydrate diet on body composition and cardiometabolic risk factors in overweight and obese males. Nutr Diabetes 2012;2:e40.
5. Pasiakos SM, Mettel JB, West K, Lofgren IE, Fernandez ML, Koo SI, Rodriguez NR. Maintenance of resting energy expenditure after weight loss in premenopausal women: potential benefits of a high-protein, reduced-calorie diet. Metabolism 2008;57:458–64.
6. Pasiakos SM, Cao JJ, Margolis LM, Sauter ER, Whigham LD, McClung JP, Rood JC, Carbone JW, Combs GF, Jr., Young AJ. Effects of high-protein diets on fat-free mass and muscle protein synthesis following weight loss: a randomized controlled trial. FASEB J 2013;27:3837–47.
7. Mettler S, Mitchell N, Tipton KD. Increased protein intake reduces lean body mass loss during weight loss in athletes. Med Sci Sports Exerc 2010;42:326–37.
8. Layman DK, Erickson DJ, Painter JE, Boileau RA, Shiue H, Sather C, Christou DD. A reduced ratio of dietary carbohydrate to protein improves body composition and blood lipid profiles during weight loss in adult women. J Nutr 2003;133:411–7.
9. Layman DK, Evans E, Baum JI, Seyler J, Erickson DJ, Boileau RA. Dietary protein and exercise have additive effects on body composition during weight loss in adult women. J Nutr 2005;135:1903–10.
10. Layman DK, Evans EM, Erickson D, Seyler J, Weber J, Bagshaw D, Griel A, Psota T, Kris-Etherton P. A moderate-protein diet produces sustained weight loss and long-term changes in body composition and blood lipids in obese adults. J Nutr 2009;139:514–21.
11. Dong JY, Zhang ZL, Wang PY, Qin LQ. Effects of high-protein diets on body weight, glycaemic control, blood lipids and blood pressure in type 2 diabetes: meta-analysis of randomised controlled trials. Br J Nutr 2013;110:781–9.
12. Gardner CD, Kiazand A, Alhassan S, Kim S, Stafford RS, Balise RR, Kraemer HC, King AC. Comparison of the Atkins, Zone, Ornish, and LEARN diets for change in weight and related risk factors among overweight premenopausal women: the A TO Z Weight Loss Study: a randomized trial. JAMA 2007;297:969–77.
13. Te Morenga LA, Levers MT, Williams SM, Brown RC, Mann J. Comparison of high protein and high fiber weight-loss diets in women with risk factors for the metabolic syndrome: a randomized trial. Nutr J 2011;10:40.
14. Layman DK, Shiue H, Sather C, Erickson DJ, Baum J. Increased dietary protein modifies glucose and insulin homeostasis in adult women during weight loss. J Nutr 2003;133:405–10.
15. Clifton PM, Bastiaans K, Keogh JB. High protein diets decrease total and abdominal fat and improve CVD risk profile in overweight and obese men and women with elevated triacylglycerol. Nutr Metab Cardiovasc Dis 2009;19:548–54.
16. Noakes M, Keogh JB, Foster PR, Clifton PM. Effect of an energy-restricted, high-protein, low-fat diet relative to a conventional high-carbohydrate, low-fat diet on weight loss, body composition, nutritional status, and markers of cardiovascular health in obese women. Am J Clin Nutr 2005;81:1298–306.
17. Nordmann AJ, Nordmann A, Briel M, Keller U, Yancy WS, Jr., Brehm BJ, Bucher HC. Effects of low-carbohydrate vs low-fat diets on weight loss and cardiovascular risk factors: a meta-analysis of randomized controlled trials. Arch Intern Med 2006;166:285–93.
18. US Department of Agriculture, US Department of Health and Human Services. Dietary guidelines for Americans, 2010. 7th ed. Washington (DC): US Government Printing Office; 2010.
19. Lichtenstein AH, Appel LJ, Brands M, Carnethon M, Daniels S, Franch HA, Franklin B, Kris-Etherton P, Harris WS, Howard B, et al. Diet and lifestyle recommendations revision 2006: a scientific statement from the American Heart Association Nutrition Committee. Circulation 2006;114:82–96.
20. Levine ME, Suarez JA, Brandhorst S, Balasubramanian P, Cheng CW, Madia F, Fontana L, Mirisola MG, Guevara-Aguirre J, Wan J, et al. Low protein intake is associated with a major reduction in IGF-1, cancer, and overall mortality in the 65 and younger but not older population. Cell Metab 2014;19:407–17.
21. Campbell TC. Dietary protein, growth factors, and cancer. Am J Clin Nutr 2007;85:1667.
22. Denke MA. Metabolic effects of high-protein, low-carbohydrate diets. Am J Cardiol 2001;88:59–61.
23. Kappagoda CT, Hyson DA, Amsterdam EA. Low-carbohydrate-high-protein diets: is there a place for them in clinical cardiology? J Am Coll Cardiol 2004;43:725–30.
24. Fukagawa NK. Protein requirements: methodologic controversy amid a call for change. Am J Clin Nutr 2014;99:761–2.
25. Layman DK. Dietary guidelines should reflect new understandings about adult protein needs. Nutr Metab (Lond) 2009;6:12.
26. Tang M, McCabe GP, Elango R, Pencharz PB, Ball RO, Campbell WW. Assessment of protein requirement in octogenarian women with use of the indicator amino acid oxidation technique. Am J Clin Nutr 2014;99:891–8.
27. Wolfe RR, Miller SL. The recommended dietary allowance of protein: a misunderstood concept. JAMA 2008;299:2891–3.
28. Lagiou P, Sandin S, Lof M, Trichopoulos D, Adami HO, Weiderpass E. Low carbohydrate-high protein diet and incidence of cardiovascular diseases in Swedish women: prospective cohort study. BMJ 2012;344:e4026.
29. Fung TT, van Dam RM, Hankinson SE, Stampfer M, Willett WC, Hu FB. Low-carbohydrate diets and all-cause and cause-specific mortality: two cohort studies. Ann Intern Med 2010;153:289–98.
30. Trichopoulou A, Psaltopoulou T, Orfanos P, Hsieh CC, Trichopoulos D. Low-carbohydrate-high-protein diet and long-term survival in a general population cohort. Eur J Clin Nutr 2007;61:575–81.
31. US Department of Agriculture ARS, Beltsville Human Nutrition Research Center, Food Surveys Research Group, US Department of Health and Human Services, Centers for Disease Control and Prevention, et al. What we eat in America, NHANES 2001–2002 through 2009–2010. 2012 Feb 9; [cited 2014 Jan 22]. Available from: http://wwwn.cdc.gov/nchs/nhanes/search/datapage.aspx?Component=Dietary.
32. Institute NC. Usual dietary intakes: SAS macros for analysis of a single dietary component 2010; [cited 2014 Apr 17]. Available from: http://appliedresearch.cancer.gov/diet/usualintakes/macros.html.
33. National Health and Nutrition Examination Survey—examination files, 2010 ed. Atlanta (GA): CDC National Health Center for Health Statistics; 2012. [cited 2014 Jan 22]. Available from: http://wwwn.cdc.gov/nchs/nhanes/search/datapage.aspx?Component=Examination.
34. National Health and Nutrition Examination Survey—laboratory files. Atlanta (GA): CDC National Health Center for Health Statistics [cited 2014 Jan 22]. Available from: http://wwwn.cdc.gov/nchs/nhanes/search/datapage.aspx?Component=Laboratory.
35. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985;28:412–9.
36. Johnson CL, Paulose-Ram R, Ogden CL, Carroll MD, Kruszon-Moran D, Dohrmann SM, Curtin LR. National health and nutrition examination survey: analytic guidelines, 1999–2010. Vital Health Stat 2 2013;161:1–24.
37. National Academy of Sciences, Institute of Medicine, Food and Nutrition Board. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. Washington (DC): National Academy of Sciences; 2005.
38. Rennie MJ. Anabolic resistance: the effects of aging, sexual dimorphism, and immobilization on human muscle protein turnover. Appl Physiol Nutr Metab 2009;34:377–81.
39. Katsanos CS, Kobayashi H, Sheffield-Moore M, Aarsland A, Wolfe RR. A high proportion of leucine is required for optimal stimulation of the rate of muscle protein synthesis by essential amino acids in the elderly. Am J Physiol Endocrinol Metab 2006;291:E381–7.
40. Paddon-Jones D, Sheffield-Moore M, Katsanos CS, Zhang XJ, Wolfe RR. Differential stimulation of muscle protein synthesis in elderly humans following isocaloric ingestion of amino acids or whey protein. Exp Gerontol 2006;41:215–9.
41. Paddon-Jones D, Rasmussen BB. Dietary protein recommendations and the prevention of sarcopenia. Curr Opin Clin Nutr Metab Care 2009;12:86–90.
42. Phillips SM. Dietary protein for athletes: from requirements to metabolic advantage. Appl Physiol Nutr Metab 2006;31:647–54.

43. Clifton PM, Condo D, Keogh JB. Long term weight maintenance after advice to consume low carbohydrate, higher protein diets—a systematic review and meta analysis. Nutr Metab Cardiovasc Dis 2014;24:224–35.
44. Rodriguez NR, Di Marco NM, Langley S. American College of Sports Medicine position stand. Nutrition and athletic performance. Med Sci Sports Exerc 2009;41:709–31.
45. Department of the Army. Nutrition standards and education. Washington (DC): Headquarters, Departments of the Army, Navy, and Air Force; 2001.
46. Pasiakos SM, Austin KG, Lieberman HR, Askew EW. Efficacy and safety of protein supplements for U.S. Armed Forces personnel: consensus statement. J Nutr 2013;143:1811S–4S.
47. Walker DK, Dickinson JM, Timmerman KL, Drummond MJ, Reidy PT, Fry CS, Gundermann DM, Rasmussen BB. Exercise, amino acids, and aging in the control of human muscle protein synthesis. Med Sci Sports Exerc 2011;43:2249–58.
48. Tang M, Armstrong CL, Leidy HJ, Campbell WW. Normal vs. high-protein weight loss diets in men: effects on body composition and indices of metabolic syndrome. Obesity (Silver Spring) 2013;21:E204–10.
49. Tang M, Leidy HJ, Campbell WW. Regional, but not total, body composition changes in overweight and obese adults consuming a higher protein, energy-restricted diet are sex specific. Nutr Res 2013;33:629–35.
50. Fulgoni, 3rd VL. Current protein intake in America: analysis of the National Health and Nutrition Examination Survey, 2003–2004. Am J Clin Nutr 2008;87:1554S–7S.
51. Schoeller DA, Thomas D, Archer E, Heymsfield SB, Blair SN, Goran MI, Hill JO, Atkinson RL, Corkey BE, Foreyt J, et al. Self-report-based estimates of energy intake offer an inadequate basis for scientific conclusions. Am J Clin Nutr 2013;97:1413–5.