Protein Intake Protects against Weight Loss in Healthy Community-Dwelling Older Adults\textsuperscript{1,2}

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Abstract

Weight loss is prevalent in the elderly population, with deleterious health consequences, notably loss of lean body mass and subsequent functional decline. Protein intake below the current RDA \([0.8 \text{ g/(kg \cdot d)}\] is also common in older adults; however, the link between the 2 has received little attention. Our objective was to assess the relation between protein intake and incident 1-y weight loss \(\geq 5\%\) in community-dwelling older adults. We conducted a nested, prospective, case-control study in 1793 community-living elderly participants of the Quebec Longitudinal Study of Nutrition as a Determinant of Successful Aging (NuAge). We studied 211 incident cases of 1-y weight loss \((\geq 5\%)\) and 211 weight-stable controls \((\pm 2\%)\) matched by sex and age category \((70 \pm 2, 75 \pm 2, \text{ and } 80 \pm 2 \text{ y})\). Diet was measured by 3 nonconsecutive 24-h recalls. ORs \((95\% \text{ CIs})\) for the association between protein intake and weight loss were computed by using conditional logistic regression. After adjustment for body mass index, energy intake, appetite, smoking status, physical activity level, physical function, chronic diseases and medications, depressive symptoms, and serum albumin and ultrasensitive C-reactive protein, the ORs of weight loss in participants with low protein intakes \([<0.8 \text{ g/(kg \cdot d)}]\) were 2.56 \((95\% \text{ CI: } 1.01, 6.50)\) compared with participants with very high protein intakes \([\geq 1.2 \text{ g/(kg \cdot d)}]\). Corresponding numbers were 2.15 \((95\% \text{ CI: } 1.02, 4.56)\) in participants with moderate protein intakes \([0.8-<1.0 \text{ g/(kg \cdot d)}]\) and 1.33 \((95\% \text{ CI: } 0.77, 2.28)\) in participants with high protein intakes \([1.0-1.2 \text{ g/(kg \cdot d)}]\). Our results suggest that protein intakes \(>1.0 \text{ g/(kg \cdot d)}\) are protective against weight loss in healthy older adults. These findings add epidemiologic evidence in support of higher optimal protein intakes than the current guidelines for healthy older adults. \textit{J. Nutr.} 144: 321–326, 2014.

Introduction

In contrast to younger age groups, adults >70 y of age are more likely to lose than to gain weight \((1,2)\), with numerous negative health consequences. Losing weight in older adults is an important risk factor for frailty \((3,4)\), mobility limitations \((5)\), disability \((6)\), and institutionalization \((7)\). Weight loss has also been linked to decreased survival \((8)\), even in overweight or obese individuals \((9)\). Thus, prevention of weight loss in healthy elderly persons may help maintain health and autonomy, with obvious economic benefits in view of the global demographic increase in this segment of the population.

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12  K.G.-D. and D.S.-A.-M. contributed equally to this work.

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Weight loss is clearly a function of insufficient energy intake, which is also prevalent in healthy older adults \((10,11)\). Significant increases in circulating proinflammatory cytokines and cortisol due to caloric insufficiency are among the mechanistic triggers thought to contribute to loss of lean mass \((12-14)\). Furthermore, low energy intake is closely linked to low protein intake in free-living and institutionalized elderly individuals \((15)\). Protein consumption is of particular interest because dietary protein intake is known to attenuate, if not prevent, the loss of lean mass \((16,17)\), which may account for \(>25\%\) of lost weight \((1,18)\). Higher protein intake is also associated with slower rates of decline in physical function and performance in women \((19)\).

Protein consumption tends to decrease with age \((20)\), and estimates of intakes below the current RDA guidelines \([<0.8 \text{ g/(kg \cdot d)}]\) \((21)\) range from \(15\%\) to \(35\%\) \((10,22,23)\). There is mounting evidence to suggest that intakes of \(\geq 1.2 \text{ g/(kg \cdot d)}\) of protein may be necessary for optimal health in an older population \((24)\). In this light, reports indicate that between \(50\%\) and \(75\%\) of older men and women have protein intakes

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<1.2 g/(kg·d) (10,21,23). The role of protein intake in relation to loss of body weight in older adults, outside of the obesity paradigm, has received very little attention. The objective of this study was to evaluate the impact of protein intake on weight loss in an independent community-dwelling elderly population.

The Quebec Longitudinal Study of Nutrition as a Determinant of Successful Aging (NuAge)13 provides excellent data on diet and other nutritional, functional, and health data from a cohort of 1793 apparently healthy and well-functioning community-dwelling elderly men and women. We used a population-based, nested case-control approach to investigate the relation between protein intake and 1-y weight loss while controlling for several potential confounders.

Participants and Methods

Study population. The present sex- and age-matched prospective case-control study was carried out within a longitudinal population-based cohort study on nutrition as a determinant of successful aging (NuAge) conducted in Quebec, Canada, from 2003 to 2008. The recruitment strategy has been described in detail elsewhere (25). Briefly, participants were recruited from a random sample of the Quebec provincial health database. Individuals unable to climb 10 steps or walk 100 m without rest and those with disabilities in daily living activities, cognitive deficits [Modified Mini Mental State Examination score ≤80 (26)], class II heart failure, chronic obstructive pulmonary disease requiring home oxygen therapy or oral steroids, inflammatory digestive diseases, or cancer requiring treatment in the 5 y before enrollment were excluded. The final NuAge sample comprised 1793 apparently healthy men and women living in the community, stratified into the following 3 age categories: 70 ± 2, 75 ± 2, and 80 ± 2 y. Data collection was carried out during annual face-to-face interviews. All participants provided written informed consent. The original study was approved by the ethics committees of the Institut Universitaire de Gériatrie de Sherbrooke and the Institut Universitaire de Gériatrie de Montréal. The present work was further approved by the McGill University ethics committee, and data access was approved by the ethics committee of the Health and Social Services Centre–Institut Universitaire de Gériatrie de Sherbrooke.

Study design. A nested case-control study was carried out; this design allowed for exact matching of the 211 participants who had substantial weight loss while controlling for age and sex.

Definition of cases and controls. Incident cases were defined as participants with a weight loss ≥5% over 1 y because this degree of weight loss is associated with increased mortality (27). Controls were defined as those with a 1-y weight change ≤2%. This definition was based on studies indicating increased mortality in elderly participants, even with weight changes as low as 2% (28).

Selection of cases and controls. Of the complete cohort, 279 participants were further excluded, as follows: 6 dropped out near the study onset; 46 had died by 6 mo after the observation period; 7 were diagnosed with cancer before 6 mo after the follow-up period; 88 were lost to follow-up; and 132 had missing weight measurements. The final studied cohort comprised 1514 participants.

A stratified sampling method without replacement was used to select cases and controls as follows: Incident 1-y cases were selected from the first-year follow-up (weight loss ≥5% year 1 – baseline) (n = 129) and second-year follow-up (weight loss ≥5% year 2 – year 1) (n = 82) visits, first-year cases were not eligible as second-year cases or controls, but first-year controls could be selected as second-year cases (n = 8). Cases were matched (1:1) by sex and age category (70 ± 2, 75 ± 2, and 80 ± 2 y) with controls who were randomly selected from eligible weight-stable participants (as defined above) from the corresponding time period. Cases from the first time period did not differ from cases selected from the second time period with respect to sex, age, BMI, energy and protein intake, and percentage of 1-y weight change (all P > 0.10). The same was true for controls.

Outcome variable. Body weight was measured with participants dressed in light indoor clothing without shoes by using a calibrated balance beam scale (Detecto-medici; Detecto Scales). The percentage of 1-y weight change was calculated as follow-up body weight minus baseline body weight, divided by baseline body weight × 100.

Energy and macronutrient intakes. Intakes of energy and macronutrients were estimated at baseline by using 3 nonconsecutive 24-h dietary recalls (1 face-to-face and 2 telephone interviews), including 1 weekend day (29). The 24-h recall interviews were conducted by trained registered dietitians. Interviewers used graduated utensils and photos of standardized food portions to enhance portion-size estimation. Dietary analysis was based on the 2007 Canadian Nutrient File, Health Canada, by using CANDAT software (Godin and Associates) augmented by a set of >300 foods by the NuAge research team. Average daily intakes of energy and protein were expressed per unit kilogram of body weight. Protein intake was further categorized as follows: low [<0.8 g/(kg·d)], moderate [0.8–<1.0 g/(kg·d)], high [1.0–<1.2 g/(kg·d)], and very high [≥1.2 g/(kg·d)].

Study covariates. Covariates were measured at baseline for cases selected from the first year of follow-up and at year 1 for those selected from the second year of follow-up. Potential confounders included BMI, total energy intake, appetite (30), dieting to lose weight, smoking status, physical activity level (31), physical function (32), depressive symptoms (33), chronic disease burden (34), polypharmacy (35), and low serum albumin and elevated ultrasensitive C-reactive protein (CRP) concentrations (36). BMI was calculated as body weight (kg)/height (m2). Height was measured with a stadiometer (Takei). Because only 2 participants had a BMI <18.5 at recruitment, a 3-category variable was created for BMI as follows: BMI <25, 25 ≤ BMI < 30, and BMI ≥30. Perception of appetite was measured by using a 10-point Likert scale (1 = poor, 10 = excellent). Those who responded “yes” to the question: “Are you following a diet to lose weight?” were classified as dieting to lose weight. Physical activity score was quantified by using the Physical Activity Scale for the Elderly questionnaire (37). Physical function score was based on a total of 8 strength/mobility tests, ranging from 0 (worst) to 32 (best) (32). Depressive symptoms were assessed by using the 30-item Geriatric Depressive Scale (38).

Participants self-reported the presence or absence of chronic diseases, such as arthritis, hypertension, cardiac conditions, diabetes, etc. The reported total number of chronic conditions and number of current medications were recorded. Serum albumin concentration was assessed in clinical biochemistry laboratories at each study site from venous blood after an overnight fast. Analyses were performed on automated analyzers (Ortho Vitros 950; Ortho-Clinical Diagnostics; or UniCel Dxc 600 Synchront; Beckman Coulter) by using the bromocresol green dye binding assay. Because chronic inflammation is a known factor of weight loss with aging (39), circulating ultrasensitive CRP was assessed. Concentrations of serum CRP were measured at the Centre Hospitalier de l’Université de Montréal clinical biochemistry laboratory by using an ultrasensitive competitive immunoassay and the BN ProSpec system from Dade Behring. The sensitivity threshold was 0.175 mg/L for a 1:20 dilution sample. Samples were measured in duplicate, with the average value used for data analyses. Intra- and interassay CVs for CRP were in the range of 3.1–4.4% and 2.5–5.7%, respectively. Finally, because loss of lean mass is an issue of interest when evaluating the effect of protein intake on weight loss and because body composition data were measured at baseline and 2 y later in a subset of the NuAge participants, we identified 60 pairs of cases and controls for whom lean body mass information was available at both time points. Fat mass (FM) and fat-free mass (FFM) were measured in a supine position by using the DXA method (GE Prodigy Lunar). This method allows for separation of the body into total and regional bone, FM, and FFM. The CVs for repeated

13 Abbreviations used: CRP, C-reactive protein; FFM, fat-free mass; FM, fat mass; NuAge, Quebec Longitudinal Study of Nutrition as a Determinant of Successful Aging.
determinations of FM and FFM in 10 adults (measured 1 wk apart) were 5.7% and 1.1%, respectively, in our laboratory. Total lean body mass was used in the analyses.

**Statistical analyses.** Values for all independent variables for each case/control pair were taken from the baseline of the corresponding time period from which the pair was selected. Values in the text are presented as means ± SDs or percentages.

Baseline characteristics including BMI, lifestyle habits, physical function, depressive symptoms, chronic disease burden, polypharmacy, and biomarkers (albumin and CRP) were compared by using t-, Mann-Whitney, or chi-square tests as appropriate. The distribution of protein intake according to the above-defined categories was examined by using the chi-square test. Linear trend was assessed by using the linear-by-linear association chi-square test.

Conditional logistic regression modeling conditioned on sex and the 3 age categories defined above was used in all regression analyses for 1-y weight loss. We separately examined the effect of energy and macronutrient intakes by using unadjusted models. Dummy variables were created for the protein intake categories with the very high category being the reference category. Unadjusted intake was categorized by using quartile scores based on cutoff values from its distribution in the complete cohort at the corresponding time period from which a pair was selected.

For each macronutrient, both energy intake and the macronutrient intake were forced into the model. In these models, energy was also examined separately in models adjusting for energy intake. The effect of each macronutrient was also examined in models adjusting for energy intake. Dummy variables were created for the protein intake categories with the very high category being the reference category. Unadjusted models and a fully adjusted model were computed.

All statistical analyses were carried out by using SPSS 14.0.1 for Windows (33). Results with 2-tailed P values <0.05 were considered significant.

**Results**

A total of 422 participants (211 cases, 211 controls) who met established definition and pairing criteria (see Participants and Methods) were included in this study. There were 121 female (57.3%) and 90 male matched pairs. Female and male cases did not differ in terms of protein intakes per unit of body weight, baseline BMI, or percentage of weight change, nor did the female and male controls (all P > 0.20). Cases and controls did not differ with respect to the age-matching condition (74.5 ± 4.3 and 74.4 ± 4.0 y, respectively; P = 0.82); therefore, no further adjustments for age were made in regression models. Dietary recall data were missing for 1 case; hence, data from the matched weight-stable controls were also excluded.

The average 2-y loss of lean body mass was 1610 ± 1680 g in cases and 1050 ± 1200 g in controls. The t test for paired samples revealed that this difference of 560 g was significant (P = 0.034).

Selected baseline covariates (nutritional attributes, smoking, physical activity and function, diseases, medications, and albumin) of cases and controls are presented in Table 1. Cases had a significantly greater number of chronic diseases and medications and lower mean physical function scores than controls. Mean serum albumin concentrations were lower in cases than in controls. Furthermore, we found a greater proportion of smokers among cases than among controls. No other significant associations were found with respect to the selected covariates.

The average contribution of protein intake to total energy intake of cases and controls did not differ (16.3% vs. 16.4%, P = 0.81). However, as shown in Table 2, mean energy, protein, and

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**TABLE 1** Baseline characteristics of weight-loss cases and weight-stable controls

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (n = 211)</th>
<th>Controls (n = 211)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI, kg/m²</td>
<td>28.2 ± 5.0</td>
<td>27.6 ± 4.7</td>
<td>0.28</td>
</tr>
<tr>
<td>&lt;25</td>
<td>50 (23.7)</td>
<td>64 (30.3)</td>
<td>0.17</td>
</tr>
<tr>
<td>25–&lt;30</td>
<td>100 (47.4)</td>
<td>100 (47.4)</td>
<td>0.013</td>
</tr>
<tr>
<td>≥30</td>
<td>61 (28.9)</td>
<td>47 (22.3)</td>
<td>0.58</td>
</tr>
<tr>
<td>Eating to lose weight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9 (4.3)</td>
<td>7 (3.3)</td>
<td>0.61</td>
</tr>
<tr>
<td>Appetite score</td>
<td>6.9 ± 2.0</td>
<td>7.0 ± 2.0</td>
<td>0.83</td>
</tr>
<tr>
<td>Smoking currently</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>16 (7.6)</td>
<td>5 (2.4)</td>
<td>0.014</td>
</tr>
<tr>
<td>PASE</td>
<td>90.5 ± 47.7</td>
<td>98.2 ± 50.1</td>
<td>0.11</td>
</tr>
<tr>
<td>Physical function</td>
<td>19.0 ± 6.2</td>
<td>20.5 ± 6.0</td>
<td>0.003</td>
</tr>
<tr>
<td>GDS</td>
<td>4.8 ± 3.9</td>
<td>5.0 ± 4.4</td>
<td>0.58</td>
</tr>
<tr>
<td>Chronic diseases, n</td>
<td>4.1 ± 2.1</td>
<td>3.6 ± 2.0</td>
<td>0.028</td>
</tr>
<tr>
<td>Medications, n</td>
<td>5.4 ± 3.3</td>
<td>4.3 ± 2.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Serum albumin, g/L</td>
<td>39.6 ± 3.0</td>
<td>38.6 ± 3.0</td>
<td>0.018</td>
</tr>
</tbody>
</table>

1 Values are n (%) or means ± SDs; P values were derived by using t-, Mann-Whitney, or Pearson chi-square tests as appropriate. GDS, 30-item Geriatric Depression Scale; PASE, Physical Activity Scale for the Elderly.

2 Possible score range: 0 (worst) to 10 (best).

3 Possible score range: 0 (worst) to 32 (best).

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**TABLE 2** Energy and macronutrient intakes as predictors of weight loss in community-dwelling older adults

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (n = 211)</th>
<th>Controls (n = 211)</th>
<th>P²</th>
<th>OR (95% CI)</th>
<th>Parameter estimate</th>
<th>Parameter estimate</th>
<th>Likelihood ratio</th>
<th>Likelihood ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy, kcal/d</td>
<td>1810 ± 501</td>
<td>1950 ± 517</td>
<td>0.008</td>
<td>0.95 (0.91, 0.99)</td>
<td>0.006</td>
<td>0.90 (0.81, 0.99)</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>Energy, kcal/kg - d</td>
<td>25.8 ± 7.9</td>
<td>28.0 ± 8.3</td>
<td>0.008</td>
<td>0.97 (0.95, 0.99)</td>
<td>0.014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein, g/d</td>
<td>72.9 ± 22.0</td>
<td>79.1 ± 23.0</td>
<td>0.005</td>
<td>0.88 (0.81, 0.97)</td>
<td>0.007</td>
<td>0.90 (0.81, 0.99)</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>Protein, g/kg - d</td>
<td>1.03 ± 0.32</td>
<td>1.13 ± 0.35</td>
<td>0.002</td>
<td>0.46 (0.26, 0.80)</td>
<td>0.006</td>
<td>0.45 (0.20, 1.01)</td>
<td>0.053</td>
<td></td>
</tr>
<tr>
<td>Lipids, g/d</td>
<td>66.7 ± 23.6</td>
<td>73.3 ± 25.4</td>
<td>0.007</td>
<td>0.89 (0.82, 0.97)</td>
<td>0.008</td>
<td>0.90 (0.81, 1.01)</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Carbohydrates, g/d</td>
<td>232 ± 70.5</td>
<td>244 ± 69.2</td>
<td>0.008</td>
<td>0.97 (0.95, 1.00)</td>
<td>0.007</td>
<td>0.89 (0.71, 1.10)</td>
<td>0.57</td>
<td></td>
</tr>
</tbody>
</table>

1 Values are means ± SDs.

2 Comparisons of cases and controls by t test.

3 Unadjusted ORs (95% CI) for parameter estimates from conditional logistic regression models conditioned on sex and 3 age categories.

4 ORs (95% CI) for parameter estimates from conditional logistic regression models conditioned on sex and 3 age categories adjusted for energy intake. In these models, energy intake was categorized by using quartile scores based on cutoff values from its distribution in the complete cohort at the corresponding time period from which a pair was selected.

5 OR (95% CI) per 100-kcal unit of energy intake.

6 OR (95% CI) per 10-g unit of macronutrient intake.

7 For each macronutrient, both energy intake and the macronutrient intake were forced into the model.
l lipid intakes, which were analyzed in separate models, were significantly lower in cases than in controls. In particular, cases consumed 0.10 g/(kg d) less protein on average than did controls 1 y before their observed weight loss. As seen in Table 2, energy, lipid, and protein intakes each predicted weight loss in unadjusted models. When adjusting for energy intake, for each macronutrient separately, only protein intake remained significantly different in cases and controls (likelihood ratio tests, $P < 0.05$). Figure 1 shows the percentage of cases and controls in each protein-intake category. Of note, 51.9% of the cases had protein intakes <1.0 kcal/(kg · d) compared with 39.6% of the controls. Analyzes showed a significant linear association between protein-intake categories and weight loss ($P = 0.005$).

The results of conditional logistic regression modeling for 1-y weight loss by protein category are shown in Table 3. In the unadjusted model, compared with participants who consumed ≥1.2 kcal/(kg · d) of protein, those in the low-intake category [<0.8 kcal/(kg · d)] were almost twice as likely to lose weight ($P = 0.018$) and those in the moderate-intake category [0.8–<1.0 kcal/(kg · d)] were 70% more likely to lose weight ($P = 0.039$). In the fully adjusted model, the risk of losing weight in the low- and moderate-protein-intake categories was 2.56 and 2.15 times, respectively.

CRP may indicate the presence of inflammation or as yet undiagnosed illness that could partly explain the weight loss

### Discussion

Longitudinal studies on the role of protein intake on weight loss in healthy older adults are scarce despite the importance of weight loss as a risk factor for negative health outcomes (4,5,7,8). The main finding of the present study was the protective effect of protein intake on subsequent 1-y weight loss in apparently healthy elderly individuals that was independent of other nutritional factors such as energy intake, BMI, currently dieting to lose weight, appetite, and other documented predictors of weight loss.

In weight-reduction programs, some studies indicate that high-protein diets promote weight loss (40). However, in that paradigm, the reported average protein content of the diet generally contributes 25–30% of the daily energy intake, whereas in the present study, protein intake was ~16.5%. Our finding that protein intake is protective of weight loss in the healthy elderly population could be ascribed to its beneficial impact on the maintenance of lean mass in older persons (17). However, for protein intake to effectively guard against weight loss, there is the premise that a significant proportion of the lost weight consists of lean mass. Although the direct impact of protein intake on lean body mass could not be measured in this study, in a subsample of study participants we showed that cases who lost ≥5% of their body weight over a 1-y period lost, on average, 0.5 kg more lean body mass compared with controls between 2 time points 2 y apart. Furthermore, previous reports on changes in body composition with weight loss in older adults showed that the contribution of lost lean mass to overall lost weight in older adults was substantial, accounting for 44% (18) to 58% (1) of the total weight lost in men and 26% (18) to 36% (1) of the total weight lost in women over a 3- to 4-y observation period.

In support of a protective role of protein intake against weight loss, we also found a clear dose-response relation. Indeed, decreasing protein intake increases the risk of weight loss (39). We examined whether inflammation status would moderate the association between protein intake and weight loss in a subsample of 143 case-control pairs for whom CRP data were available. In a model, adjusting for BMI, energy intake, smoking status, physical function, and number of medications, further adjustments for CRP values somewhat strengthened the inverse association between protein intake and weight loss. In this model, compared with very high intakes, ORs were 3.16 (95% CI: 1.18, 8.30) for low intakes, 2.52 (95% CI: 1.08, 5.87) for moderate intakes, and 2.06 (95% CI: 0.91, 4.64) for high intakes. CRP concentration at baseline was not associated with weight loss (OR: 0.91; 95% CI: 0.55, 1.50).

### Table 3

Unadjusted and fully adjusted conditional regression models for weight loss by protein-intake category in community-dwelling older adults

<table>
<thead>
<tr>
<th>Protein-intake category</th>
<th>Unadjusted model</th>
<th>Fully adjusted model1</th>
<th>Protein-intake category</th>
<th>Unadjusted model</th>
<th>Fully adjusted model1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>Parameter estimate $P$ value</td>
<td>OR (95% CI)</td>
<td>Parameter estimate $P$ value</td>
<td></td>
</tr>
<tr>
<td>Low: &lt;0.8 g/(kg · d)</td>
<td>1.32 (1.12, 3.31)</td>
<td>0.018</td>
<td>2.56 (1.01, 6.50)</td>
<td>0.048</td>
<td></td>
</tr>
<tr>
<td>Moderate: 0.8–&lt;1.0 g/(kg · d)</td>
<td>1.71 (1.04, 2.80)</td>
<td>0.039</td>
<td>2.15 (1.02, 4.56)</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>High: 1.0–&lt;1.2 g/(kg · d)</td>
<td>1.33 (0.77, 2.28)</td>
<td>0.31</td>
<td>1.60 (0.81, 3.15)</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Very high: ≥1.2 g/(kg · d)</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
</tr>
</tbody>
</table>

1 Adjusted for energy intake, BMI, smoking, physical activity, physical function, dieting to lose weight, appetite, number of medications, number of chronic diseases, depressive symptoms, and serum albumin concentrations. All covariates were simultaneously forced in this multivariable conditional logistic regression model. In this model, except for protein intake, categorical variables were treated as continuous.

Model likelihood ratio test: chi-square = 31.797, df = 14, $P$ = 0.004, $n$ = 183 pairs.
loss such that compared with protein intakes $\geq 1.2$ g/(kg · d), the risk of losing weight was twice as likely with intakes <1.0 g/(kg · d), and >2.5 times as likely with intakes <0.8 g/(kg · d). The current RDA guideline (21) for protein intake for all adults aged $\geq 19$ y is 0.8 g/kg body weight. Nonetheless, there is growing support for the optimal protein intake in older adults to exceed the current guidelines. For example, a clinical study showed improvements in lean mass in frail older women when protein intake was increased from 0.8–1.2 g/(kg · d) (41). Also, in a report of the Health, Aging, and Body Composition Study (17), older individuals in the highest quintile of protein intake [$1.2 \pm 0.04$ g/(kg · d)] lost 40% less lean mass over a 3-y period than did those in the lowest quintile [$0.8 \pm 0.03$ g/(kg · d)]. In the present study, we found that, on average, those who lost $\geq 5\%$ of body weight over a 1-y period consumed 0.1 g/(kg · d) less protein than those whose weight remained stable over the same period. This translates into a deficit of 6.5 g/d for an average person weighing 65 kg. Our results add to the debate concerning the amount of optimal protein intake in the elderly population and suggest that protein intakes $>1.0$ g/(kg · d), which are considered safe for healthy elderly individuals (16), may be necessary to reduce the risk of weight loss and potentially of lean body mass in this population.

Participants of the NuAge cohort were apparently healthy, well-functioning older adults, and our results may not be generalizable to frail or ill older adults. Also, although we controlled for a large number of explanatory variables, confounding by other factors cannot be ruled out. For instance, inflammation, a known factor for weight loss, was tested in secondary analyses, but we found very little impact on the significant relation between protein intake and weight loss. Finally, although causality cannot be inferred from a case-control study, the relatively elevated risk of weight loss with protein intakes below the RDA, the clear gradient in the association between protein intake and risk of weight loss, and the fact that the direction is biologically plausible support the direction of the association.

Health messages regarding a healthy diet that is low in energy, fat, and cholesterol may not be suitable for maintaining optimal health for older people because many foods rich in protein are also high in fat and energy. A healthy diet for older adults should include good sources of proteins such as fish, meat, eggs, milk, and cheese.

The strengths of the present study include precise and valid measures of food types and quantities, measured body weight and height as opposed to self-reports, and the use of a biomarker to ascertain clinical status. Also, participants were recruited from 2 sites in urban, semiurban, and rural regions, increasing the potential of our results to be generalizable to a healthy older population.

Another strength of the present study lies in our choice of controls. We defined weight stability as a maximum 1-γ weight change of 2% on the basis of a study that found decreased survival even with percentage weight changes as low as 2% (28). Choosing this criterion allowed us to avoid selecting controls who were too similar to cases with respect to weight loss (i.e., 3% or 4% weight loss), which might have attenuated the findings.

In conclusion, our study supports a protective role of protein intake against weight loss. It contributes epidemiologic evidence in support of optimal protein intakes $>1.0$ g/(kg · d), which is higher than the current RDA for the prevention of weight loss in the healthy elderly population.

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