Inadequate Dietary Protein Increases Hunger and Desire to Eat in Younger and Older Men\textsuperscript{1,2}

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Abstract

Many older people experience changes in appetite and consume marginal or inadequate dietary protein. This study was designed to examine the appetitive responses to habitual protein intakes that span the range of adequacy in younger and older men. Twenty-two men (12 younger, aged 21–43 y and 10 older, aged 63–79 y) completed, in random order, three 18-d trials designed to examine the appetitive responses to habitual protein intakes that span the range of adequacy in younger and older men. Twenty-two men (12 younger, aged 21–43 y and 10 older, aged 63–79 y) completed, in random order, three 18-d trials that involved consumption of individualized, isoenergetic menus providing 1.00, 0.75, and 0.50 g protein \cdot kg BW\textsuperscript{-1} \cdot d\textsuperscript{-1}, which were 125\% (trial P125), 94\% (trial P94), and 63\% (trial P63) of the Recommended Dietary Allowance for protein. Near the end of each trial, the subjects recorded appetitive sensations hourly throughout one day using a visual analogue scale. Independent of age, ratings of hunger were lower for P125 (1.3 \pm 0.5 cm) than P94 (1.8 \pm 0.8 cm) and P63 (1.8 \pm 0.6 cm) (P = 0.037), and desire to eat was lower during the P125 trial (1.4 \pm 0.5 cm), compared with the P63 trial (2.1 \pm 0.7 cm) (P = 0.003), and P94 (1.8 \pm 0.7 cm) was not different when compared with P63 and P125. Protein intake did not influence fullness. These results show that younger and older men who consume inadequate protein experience appetite changes that may promote increased food intake. J. Nutr. 137: 1478–1482, 2007.

Introduction

Dietary protein is considered to be more satiating than carbohydrate and fat, based primarily on results from acute and short-term feeding studies (1–5). In a metaanalysis of data from 10 studies that included measurements of energy intake at the meal following a higher vs. lower protein preload, 8 of the studies indicated that subjects consumed less energy (mean 9\% lower) at the meal subsequent to the higher protein preload (6). These findings have been used to support the notion that a person’s habitual protein intake might influence their appetite and thus ingestive behavior. However, limited research has addressed the effects of habitual protein intake on appetite in humans. One 2-wk trial noted an inverse correlation between habitual protein intake and the postprandial satiety response to a high-protein meal (7).

Research in pigs (8), chickens (9), and sheep (10) indicate animal content will preferentially choose nonpurified diet with a protein content that matches their requirements or need for more protein when deprived. Rats show a preference for higher-protein nonpurified diet vs. a protein-free nonpurified diet (11). Pigs provided inadequate protein compensate by increasing total food intake (8). The impact of habitual inadequate protein intake on appetite is not readily documented in older humans, but is important to understand because 15–40\% of older Americans may consume protein at or below the recommended dietary allowance (RDA)\textsuperscript{6} of 0.8 g \cdot kg BW\textsuperscript{-1} \cdot d\textsuperscript{-1} (12,13). Previous research has shown that older persons give higher hedonic ratings to soups containing higher concentrations of casein hydrolysate than younger persons, especially when the older persons had low serum albumin concentration, a marker of poor protein nutritional status (14).

The purpose of this study was to examine the effects of protein intakes that span the range of adequacy on indices of appetite in men. We hypothesized that inadequate protein intake would increase the perception of hunger.

Methods

Subjects. Twelve younger (mean age 29 \pm 7 y, range 21–43 y) and 10 older (aged 72 \pm 6 y, range 63–79 y) men completed the study. One younger participant and 2 older participants dropped out during the study. Inclusion criteria were the following: ages of 21–45 y and 60–80 y; clinically normal heart, liver, kidney, and thyroid status; no diabetes mellitus; complete bladder control; not taking over-the-counter or prescription medications or nutritional supplements known to affect energy or protein metabolism; nonsmoker; BMI 21–30 kg/m\textsuperscript{2}; community-dwelling; ambulatory, and recreationally active, performing structured physical activities (exercise) \geq 3 d/wk; have not started a new exercise program within the past 3 mo; body weight stable (\pm 3 kg) during the past 6 mo. Potential participants responded to advertisements placed in local newspapers and flyers and underwent a phone interview. This was followed by a screening that included a medical history questionnaire,

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\textsuperscript{6} Abbreviations used: BUN, blood urea nitrogen; BW, body weight; gLMS, general labeled magnitude scale; P125, 1.0 g protein \cdot kg BW\textsuperscript{-1} \cdot d\textsuperscript{-1}; P94, 0.75 g protein \cdot kg BW\textsuperscript{-1} \cdot d\textsuperscript{-1}; P63, 0.50 g protein \cdot kg BW\textsuperscript{-1} \cdot d\textsuperscript{-1}; RDA, recommended dietary allowance.
Experimental design. The study consisted of three, 18-d trials with different dietary protein intakes utilizing a randomized, crossover design. Each trial was separated by a minimum 1-wk washout period, and during this time, the subjects were asked to consume their usual diets.

Diet. All foods and beverages, except water (ad libitum intake), were provided to the subjects throughout the 3 controlled eating periods. Each subject’s total energy requirement was estimated to equal 1.75 times their resting energy expenditure, which was predicted using the Harris-Benedict equation for men (15). The 1.75 activity factor was used instead of the more commonly used 1.60 activity factor to account for the energy expenditure of the recreational activities most of the subjects performed. The somewhat higher factor was also used to compensate for a potential overestimation of actual metabolizable energy intakes when the Atwater energy equivalents of 16.7, 16.7, and 37.7 kJ/g of protein, carbohydrate, and fat, respectively, were used to calculate the energy contents of the diets provided to the subjects (16). During each trial, if a volunteer’s weight fluctuated by ± 0.5 kg from baseline for >3 d, energy intake was adjusted for weight maintenance. On d 1 of each trial, subjects consumed a very low protein diet of 0.2 g protein · kg body weight (BW)⁻¹ · d⁻¹, which was used to enhance adaptation to the subsequent protein intake (17). On d 2–18 of each trial, the subjects consumed a 3-d cycle of lacto-ovo vegetarian, isoenergetic menus that contained 1.00 g (125% of the RDA; P125), 0.75 g (94% of the RDA; P94), or 0.50 g (63% of the RDA; P63) protein · kg BW⁻¹ · d⁻¹ and a nonprotein ratio of 65% carbohydrate and 35% fat. The sources of protein were dairy (27, 29, 12%), egg (4, 3, 2%), grains (48, 47, 57%), legumes (9, 8, 8%), and other (12, 13, 21%) for the P125, P94, and P63 trials, respectively. Subjects were instructed to rinse and scrape all food containers and to consume the rinsings. Although we relied primarily on the serum urea nitrogen (BUN) and urinary total nitrogen excretion data (see below) as independent, objective markers of dietary compliance, we also used less quantitative means to promote compliance. These included frequently questioning the subjects about their perceptions of the diets and the ingestion of any nonprotocol foods and beverages; providing each subject with a daily check-off list of the foods and beverages to be consumed; and monitoring their returned food and beverage containers, which they were requested to not wash. We did not have a formal rating assessing the acceptability of the 3-d menu cycle during the 3 trials. However, all subjects reviewed the menus prior to starting the protocol, and any extreme food aversions were discussed and limited menu changes allowed.

Subjects were given a daily multivitamin/mineral dietary supplement (Centrum, Wyeth Consumer Healthcare) and instructed to refrain from other supplements during the entire study. The ingestion of alcohol was discussed and limited menu changes allowed.

Appetite assessment. Appetite was assessed during a single 24-h period in the third week of each trial using the general labeled magnitude scale (gLMS) (19). Each subject completed the gLMS questionnaire hourly during waking hours over the 24-h period. The following questions were asked starting with “How strong is your”: feeling of hunger; feeling of fullness; desire to eat? The subjects were instructed to place a horizontal line through the vertical axis describing their feeling at that moment for each question. The vertical axis was 10.0 cm, measured using a ruler to the nearest mm. The anchors were 0.2 cm “barely detectable,” and 10.0 cm “strongest imaginable”; and the intermediate identifiers, displayed with quasi-logarithmic spacing, were 0.6 cm “weak,” 1.7 cm “moderate,” 3.4 cm “strong,” and 5.3 cm “very strong.” Each subject’s peak and mean scores were used for analyses.

Statistical analysis. Values are means ± SD. Comparisons between younger and older men and among the three trials were performed using a mixed model repeated measures ANOVA and post-hoc analyses with Tukey-Kramer (JMP Statistical Discovery Software, version 3; SAS Institute). Statistical significance was defined as $P < 0.05$.

Results

The younger and older men did not differ in body weight (78.8 ± 15.1 and 78.8 ± 11.5 kg, respectively) or BMI (24.6 ± 4.1 and 26.2 ± 3.2 kg/m²). The younger men had higher fat-free mass (61.0 ± 8.8 vs. 55.8 ± 5.4 kg) and a lower percentage of body fat (21.5 ± 7.5 vs. 28.6 ± 6.5%) than the older men.

For the 3 trials combined, total energy, carbohydrate, and fat intakes were higher for the younger men, whereas protein and fiber intakes did not differ between the 2 age groups (Table 1).

Blood urea nitrogen was lower in younger men than in older men and urinary nitrogen, a very low protein diet of 0.2 g protein · kg BW⁻¹ · d⁻¹, which was used to enhance adaptation to the subsequent protein intake (17).

### Table 1: Effect of 3 chronic protein intake levels on nitrogen assessments for younger and older men

<table>
<thead>
<tr>
<th>Protein intake</th>
<th>P125</th>
<th>P94</th>
<th>P63</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy, MJ/d</td>
<td>Younger</td>
<td>13.3 ± 2.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.2 ± 2.4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>11.8 ± 1.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.5 ± 1.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Protein, g/d</td>
<td>Younger</td>
<td>81 ± 15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>61 ± 12&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>81 ± 12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>60 ± 9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Protein intake</td>
<td>Younger</td>
<td>1.02 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.77 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>1.01 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.76 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Carbohydrate, g/d</td>
<td>Younger</td>
<td>468 ± 93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>479 ± 88&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>408 ± 72&lt;sup&gt;a&lt;/sup&gt;</td>
<td>407 ± 56&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fat, g/d</td>
<td>Younger</td>
<td>110 ± 21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>113 ± 20&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>98 ± 17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>98 ± 15&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fiber, g/d</td>
<td>Younger</td>
<td>35 ± 5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31 ± 5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>35 ± 4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>28 ± 2&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>BUN, mmol/L</td>
<td>Younger</td>
<td>4 ± 1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4 ± 1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>6 ± 1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5 ± 1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Urinary total nitrogen, mg · kg BW⁻¹ · d⁻¹</td>
<td>Younger</td>
<td>101 ± 18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>83 ± 20&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>113 ± 18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>90 ± 13&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> Values are means ± SD, $n$ = 12 (younger) and 10 (older) men.

<sup>a,b,c</sup> Main effect of protein intake, means in a row with superscripts without a common letter differ, $P < 0.05$.

<sup>x</sup> Main effect of age, means in a column with superscripts without a common letter differ, $P < 0.05$. 

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men, and urinary total nitrogen excretion did not differ between the 2 groups \((P = 0.097)\).

For the subjects combined, total energy, carbohydrate, and fat intakes did not differ among the 3 trials (Table 1). Protein intakes, expressed as g/d and g protein \(\cdot\) kg BW\(^{-1}\) \(\cdot\) d\(^{-1}\), decreased from the P125 to P94 to P63 trials. Fiber intake was higher during the P125 trial than during the P63 trial, and P94 was not different when compared with P63 and P125. Blood urea nitrogen concentration and 24-h urinary total nitrogen excretion decreased with decreasing dietary protein intakes (Table 1).

For the younger compared with the older men in all trials combined, the mean \((Y 2.1 \pm 0.8, O 2.6 \pm 0.9; (P = 0.014)) and peak \((Y 4.1 \pm 1.3, O 5.3 \pm 2.3) (P = 0.039)\) feelings of fullness were lower. In contrast, feelings of hunger and desire to eat did not differ between the age groups. Independent of age, feelings of hunger were lower for P125 than P94 and P63, and desire to eat was lower during P125, compared with P63, and P94 was not different when compared with P63 and P125 (Table 2). The main effect of protein intake (data from younger and older men combined) on hunger and desire to eat is presented in Figure 1. Also, the peak feeling of hunger was lower in P125 \((3.0 \pm 1.1)\) than P94 \((4.2 \pm 1.9)\) and P63 \((3.9 \pm 1.0)\) \((P = 0.04)\). Protein intake did not influence fullness.

**Discussion**

The primary aim of this study was to explore the effects of chronic low-to-moderate dietary protein intakes on appetitive responses in younger and older men. A controlled feeding design was used to ensure dietary compliance. The protein intake-dependent differences in BUN and urinary total nitrogen excretion confirmed that subjects followed the protocol. Previous studies primarily focused on levels of protein intake above the current estimated average requirement (EAR) of 0.66 g protein \(\cdot\) kg BW\(^{-1}\) \(\cdot\) d\(^{-1}\) and RDA of 0.80 g protein \(\cdot\) kg BW\(^{-1}\) \(\cdot\) d\(^{-1}\) \((7,20,21)\). However, because critical physiologic changes in muscle mass occur when the amount of protein consumed is at the RDA \((22,23)\) and below the EAR \((24,25)\), the current study examined protein intakes above, within, and below the normal range \((22,23)\) and below the EAR \((24,25)\), this is potentially due to decreased satiety associated with lower protein intake, a lower thermogenesis rate observed with lower protein intake, and/or lower preservation of fat-free mass \((20)\). In our study, regardless of age, hunger and desire to eat were higher when the subjects consumed diets that contained 63 and 94% of the RDA for protein, intakes that might be considered inadequate and marginal, respectively, than when 125% of the RDA for protein was consumed. These results indicate that appetitive responses are affected by the amount of protein consumed within the range of adequacy. These results also indicate that it is possible to detect differences in appetite with relatively small \((0.25 \text{ g protein} \cdot \text{kg BW}^{-1} \cdot \text{d}^{-1})\) changes in protein intake.

**TABLE 2** Daily values for appetite ratings of younger and older men after 3 chronic protein intakes

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Protein intake} & \text{P125} & \text{P94} & \text{P63} \\
\hline
\text{Hunger, cm} & \begin{array}{c}
1.4 \pm 0.5^a \\
1.2 \pm 0.5^a \\
2.1 \pm 0.8^a \\
2.5 \pm 0.9^a \\
1.4 \pm 0.6^a \\
1.3 \pm 0.5^a
\end{array} & \begin{array}{c}
1.9 \pm 0.6^b \\
2.0 \pm 0.9^b \\
2.1 \pm 0.4^b \\
2.4 \pm 1.0^b \\
1.6 \pm 0.8^b \\
1.9 \pm 0.8^b
\end{array} & \begin{array}{c}
1.7 \pm 0.5^a \\
2.0 \pm 0.7^a \\
2.0 \pm 0.6^a \\
2.4 \pm 1.0^a \\
2.0 \pm 0.4^a \\
2.4 \pm 1.0^a
\end{array} \\
\hline
\text{Fullness, cm} & \begin{array}{c}
1.4 \pm 0.5^a \\
1.2 \pm 0.5^a \\
2.1 \pm 0.8^a \\
2.6 \pm 0.9^b \\
1.4 \pm 0.6^a \\
1.3 \pm 0.5^a
\end{array} & \begin{array}{c}
1.6 \pm 0.5^a \\
2.0 \pm 0.9^a \\
1.8 \pm 0.4^a \\
2.4 \pm 1.0^a \\
1.6 \pm 0.8^a \\
1.9 \pm 0.8^a
\end{array} & \begin{array}{c}
1.7 \pm 0.5^a \\
2.0 \pm 0.7^a \\
2.0 \pm 0.6^a \\
2.4 \pm 1.0^a \\
2.0 \pm 0.4^a \\
2.4 \pm 1.0^a
\end{array} \\
\hline
\text{Desire to eat, cm} & \begin{array}{c}
1.4 \pm 0.5^a \\
1.2 \pm 0.5^a \\
2.1 \pm 0.8^a \\
2.6 \pm 0.9^b \\
1.4 \pm 0.6^a \\
1.3 \pm 0.5^a
\end{array} & \begin{array}{c}
1.6 \pm 0.5^a \\
2.0 \pm 0.9^a \\
1.8 \pm 0.4^a \\
2.4 \pm 1.0^a \\
1.6 \pm 0.8^a \\
1.9 \pm 0.8^a
\end{array} & \begin{array}{c}
1.7 \pm 0.5^a \\
2.0 \pm 0.7^a \\
2.0 \pm 0.6^a \\
2.4 \pm 1.0^a \\
2.0 \pm 0.4^a \\
2.4 \pm 1.0^a
\end{array} \\
\hline
\end{array}
\]

\(^a,b^\) Main effect of protein intake, means in a row with superscripts without a common letter differ, \(P < 0.05\).

\(^a,^b^\) Main effect of age, means in a column with superscripts without a common letter differ, \(P < 0.05\).

For the younger compared with the older men in all trials combined, the mean \((Y 2.1 \pm 0.8, O 2.6 \pm 0.9; (P = 0.014)) and peak \((Y 4.1 \pm 1.3, O 5.3 \pm 2.3) (P = 0.039)\) feelings of fullness were lower. In contrast, feelings of hunger and desire to eat did not differ between the age groups. Independent of age, feelings of hunger were lower for P125 than P94 and P63, and desire to eat was lower during P125, compared with P63, and P94 was not different when compared with P63 and P125 (Table 2). The main effect of protein intake (data from younger and older men combined) on hunger and desire to eat is presented in Figure 1. Also, the peak feeling of hunger was lower in P125 \((3.0 \pm 1.1)\) than P94 \((4.2 \pm 1.9)\) and P63 \((3.9 \pm 1.0)\) \((P = 0.04)\). Protein intake did not influence fullness.

\[\begin{align*}
\text{FIGURE 1} & \text{ Effect of 3 chronic protein intake levels in younger and older men on waking hour feeling of hunger (P125, 1.3 \pm 0.5; P94, 1.8 \pm 0.8; P63 1.8 \pm 0.6) (A) and desire to eat (P125, 1.4 \pm 0.5; P94, 1.8 \pm 0.7; P63 2.1 \pm 0.7) (B) using a generalized labeled magnitude scale. Data from younger and older men were combined because there was no effect of age. Values are means \pm SD, } n = 22. \text{ Means with superscripts without a common letter differ, } P < 0.05.
\end{align*}\]
habitual protein intake will influence their appetite response to a high-protein meal. This experiment did not evaluate the appetite responses of the 2 groups consuming meals that contained the same amounts of protein that they were habituated to, as was done for the current study.

Providing the subjects with isonenergetic-controlled diets with 3 levels of protein provided us with a unique opportunity to document their appetite responses without the confounding influence of changes in energy intake, because they were not allowed to act upon any appetite changes. A shift in motivation to eat protein has occurred in individuals who are protein deficient (14,28,29). Malnourished Mexican infants ingested ~23% more soup when it contained casein hydrolysate (18.4 ± 2.7 mL) than plain soup (14.1 ± 2.1 mL) (P < 0.01) (28). The nonmalnourished control children ate similar amounts of both soups (28). In another study measuring chemosensory perception, 26 persons tasted soup with 0, 1, 2, 3, 4, and 5% casein, w:v. Of 26 persons, 16 were elderly (aged 70–92 y) and 10 were younger (aged 18–26 y). The elderly persons had lower serum protein and albumin and higher BUN concentrations than the younger persons. The elderly persons rated the higher casein hydrolysate concentrations as more palatable than did the younger participants (14). Among the younger and elderly persons combined, persons with lower concentrations of serum albumin and persons with elevated BUN expressed greater liking for a higher concentration of casein hydrolysate (1.5 vs. 0.4%, w:v) (14). Consistent with the idea that people who consume inadequate protein show a preference for higher protein foods, Gibson et al. (29) showed, in 18–49 y-old subjects, that consumption of a lower-protein (vs. higher-protein) breakfast resulted in a preference for higher-protein flavored foods at a midday meal. Further, this preference for higher-protein flavors occurred mainly at the end of the meal. The authors suggested that the preference for protein was most likely to occur after a person’s energy needs were met. Collectively, these findings support the hypothesis that chronic ingestion of a diet containing inadequate protein, but adequate energy, elevates the motivation to eat protein, affects protein flavor preference, and triggers appetitive changes consistent with a desire to consume food.

The gLMS subjectively assesses the indices of appetite in individuals who have unique and personalized definitions for the terms “hunger,” “fullness,” and “desire to eat.” Tools like the gLMS are difficult if not impossible to validate against an objective measure such as food intake; however, when used under conditions of fixed feeding and repeated measurements within subjects, like the current study, they might provide important information that likely would not be possible to obtain from measurements of voluntary food intake (30). The gLMS is documented to be sensitive to a variety of experimental manipulations including changes in energy intake and diet composition [see (30) for review]. The use of a quasi-logarithmic scale to space the intermediate identifiers results in the potential for a relatively small quantitative change at the lower end of the scale (i.e., toward “barely detectable”) to represent a larger magnitude difference in perception than a comparable quantitative change at the higher end (i.e., toward “strongest imaginable”). The shift from below to above one of the intermediate identifiers represents an order of magnitude change in rating. These issues might be important with regard to the findings from the current study. Although statistically significant, the quantitative changes in hunger and desire to eat documented using the gLMS were relatively small (increased from P125 to P63 of ≤0.8 cm for daily mean hunger and ≤1.1 cm for daily mean desire to eat, on a 10 cm full range gLMS). These changes, however, shifted the mean values from between the “weak” and “moderate” identifiers to between the “moderate” and “strong” identifiers. Likewise, peak hunger shifted from between the “moderate” and “strong” identifiers to between the “strong” and “very strong” identifiers.

Appetite changes with age, and the anorexia of aging may relate to numerous social, psychological, hormonal, and medical factors that collectively result in inadequate feeding (31–33). The present finding, that the older men perceived greater fullness than the younger men despite consuming less total energy daily, supports observations that older men are generally more satiated (34) and become satiated more quickly during a meal (35). Some researchers have reported an age-related decrease in hunger (36), although this was not observed in our study. It is important to note, however, that the use of a controlled feeding experimental design limits generalization of these findings to an ad libitum diet.

As protein was varied to specified amounts, fat and carbohydrate did not change. Thus, the consistency of these macronutrients (as a percentage of nonprotein energy) likely minimized macronutrient influences on appetite. Trial-dependent differences in fiber intake occurred and could have confounded the results. However, the finding that hunger was significantly different between the P125 and P94 trials when there were no differences in fiber intake, argue against fiber being the dominant dietary factor causing the differential appetite responses among trials. All fiber intakes were generally 25–35 g/d. Recent studies have demonstrated that fiber has a limited effect on appetite (37–42). Overall, this indicates the results presented are likely due to the differences in dietary protein, not fiber. The results of this study indicate that inadequate dietary protein intake leads to increased hunger and desire to eat in men.

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Literature Cited


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