

# Dietary Variety Predicts Low Body Mass Index and Inadequate Macronutrient and Micronutrient Intakes in Community-Dwelling Older Adults

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**Background.** Low body mass index (BMI) and micronutrient deficiencies are associated with increased morbidity and mortality rates in old age. Whether adverse patterns of dietary variety predict both low BMI and low micronutrient intakes in older adults was investigated.

**Methods.** A cross-sectional analysis of national survey data was conducted in 1174 healthy adult men and women (ages 21 to 90 years) who provided physiologically plausible dietary data in the 1994–1996 Continuing Survey of Food Intakes by Individuals. Measurements included reported energy intake, protein intake (percentage meeting Recommended Dietary Allowance), micronutrient intakes (percentage meeting Estimated Average Requirements for 14 micronutrients), and BMI.

**Results.** Adults who were 61 years or older consumed a greater total variety of foods, chose foods from a wider range of food groups, had a greater variety of micronutrient-dense foods and energy-weak foods, and had a lower variety of micronutrient-weak foods compared with adults ages 21 to 60 years ( $p < .05$  to  $.001$ ). However, older adults with low BMIs ( $<22 \text{ kg/m}^2$ ) consumed a lower variety of energy-dense foods compared with older adults with higher BMIs ( $p < .05$ ). The variety of energy-dense foods predicted both energy intake and BMI at all ages in multiple regression models controlling for confounding variables ( $R^2 = .124$  for energy,  $R^2 = .574$  for BMI,  $p < .001$ ). A higher percentage of older persons had inadequate micronutrient intakes compared with younger persons ( $p < .05$ ), especially vitamin E, calcium, and magnesium, but consumption of a particularly wide variety of micronutrient-rich foods helped counterbalance these trends ( $p < .05$ ). Older adults who had a low BMI and consumed a low variety of micronutrient-dense foods were particularly at nutritional risk, with only 65.4% consuming the Recommended Dietary Allowance for protein and none meeting the Estimated Average Requirements for all 14 micronutrients.

**Conclusions.** In contrast to previous suggestions that older persons consume a monotonous diet, this study showed that adults who were 61 years or older consumed a greater total food variety, and a greater variety of micronutrient-dense and energy-weak foods, compared with adults who were 60 years or younger. Although consumption of a low variety of energy-dense foods may contribute to reduced energy intake and body weight at any age, the variety of micronutrient-dense foods consumed needs to increase in old age to prevent micronutrient deficiencies. These findings suggest that all adults need advice on the changing needs for dietary variety with aging to maintain health, and that older persons with low BMI are particularly vulnerable to dietary shortfalls.

**W**eight loss and low body mass index (BMI) in old age are associated with frailty and accelerated morbidity and mortality rates (1–10), and they are thought to be caused, at least in part, by low energy intake. Impaired regulation of food intake and adverse medical and social factors have been suggested to underlie the changes in energy intake in old age (11–13), but little is known about other potential determinants of inadequate dietary energy in elderly persons.

Low dietary variety could theoretically lead to inadequate intakes of energy and other nutrients, and it is a factor that could be reversed with simple dietary education. Studies in animal models and humans (14–17) have consistently demonstrated a strong positive effect of dietary variety on food intake within and between meals. When the variety of food items consumed is wide and also energy dense, higher energy intake and higher percentage body fat are also reported (16). With regard to aging, low dietary variety

could have the opposite effect, namely reducing energy intake and causing weight loss.

However, to our knowledge, few studies have been published on changes in dietary variety with aging. These suggest both an increase (18) and a decrease in total variety (19,20). The controversy is probably a result of several methodologic factors, including widespread underreporting of dietary intake (21) and inclusion of some participants with physiologically implausible dietary data (22). In addition, most of the studies were on small, nonrepresentative populations of exclusively elderly persons (that is, they had no young control group), and they generally discounted dietary variety from nonhealthful (generally energy-dense) foods. It would be difficult, therefore, to identify an association between different types of dietary variety and body weight in old age based on past studies, and further work in this area is needed.

In addition to its theoretical effects on macronutrient intakes and body weight, low dietary variety increases the

Table 1. Participant Characteristics (Mean  $\pm$  SD\*)

Characteristic	Younger	Older
	21–60 Years	61–90 Years
N (M, F)	892 (533 M, 359 F)	282 (163 M, 99 F)
Age, y* <sup>†</sup>	39.7 $\pm$ 10.9	71.1 $\pm$ 7.5
Height, cm* <sup>‡</sup>	173.0 $\pm$ 10.2	169.6 $\pm$ 9.8
Weight, kg* <sup>†</sup>	75.5 $\pm$ 15.6	72.8 $\pm$ 14.1
BMI, kg/m <sup>2</sup> * <sup>‡</sup>	25.0 $\pm$ 3.9	21.2 $\pm$ 3.7
Physical inactivity (TV viewing, h/wk)* <sup>‡</sup>	2.0 $\pm$ 1.6	2.9 $\pm$ 1.9
Household income, \$1000/y <sup>†</sup>	52.5 $\pm$ 27.1	37.5 $\pm$ 27.1
Education, y <sup>†</sup>	14.3 $\pm$ 2.4	12.6 $\pm$ 3.2

Note: \*Values are adjusted for sex due to significant differences between men and women in the two age groups for these variables.

<sup>†</sup>Significant difference between age groups,  $p < .05$ .

<sup>‡</sup>Significant difference between age groups,  $p < .001$ .

SD = standard deviation; M = male; F = female; BMI = body mass index.

risk for micronutrient deficiencies (18,23). Micronutrient deficiencies are common in elderly populations (23–26) and are thought to prolong recovery from injury (27); exacerbate a wide range of problems such as cognitive decline, frailty, and osteoporosis (28–31); and accelerate the mortality process (4). However, we do not know whether low dietary variety is an important contributor to the observed micronutrient shortfalls in old age.

Therefore, we conducted an analysis of national dietary survey data to address two related questions. First, is low dietary variety within particular classes of foods a risk factor for low energy intake and low BMI in old age? Second, how do different types of dietary variety typically differ between younger and older adults, and what do the differences imply for maintaining adequate protein and micronutrient status in old age?

## METHODS

### Survey Design and Sample

We derived our study sample from the 1994–1996 Continuing Survey of Food Intakes by Individuals (CSFII 1994–96) (32). As described, the CSFII 1994–96 is a nationally representative survey of 16,103 community-dwelling persons ages 0 to 90 years living in the United States. Demographic and other information were collected by in-person interview. Dietary information was collected during 1 or 2 prearranged days approximately 10 days apart by using the multiple-pass 24-hour recall method, with most of these interviews conducted in person.

For the purposes of the current analysis, we limited the study sample to apparently healthy white persons who were 21 years or older and who completed both days of dietary recall and for whom information on self-reported height and weight was complete. Exclusion criteria were: pregnancy or lactation; being a current smoker; having a BMI  $< 17$  kg/m<sup>2</sup>; past or present occurrence of diabetes, hypertension, coronary artery disease, cancer, hypercholesterolemia, or stroke; obtaining food from a soup kitchen or Meals on Wheels on the days of the interview; use of low-fiber diets due to a medical condition or prescription by a physician; use of a bland diet for ulcer prevention or treatment; and self-

reported severe food insecurity (often not having enough food to eat). We also excluded persons who reported physiologically implausible energy intakes ( $\geq 30\%$  of predicted energy requirements [33]), based on our previous analysis that showed that the inclusion of such persons substantially biases the relationship between dietary intake and outcome measurements in regression analyses (22).

The total sample size for the current study was 1174. The characteristics of the persons in the study sample ages 21 years and older who reported both height and weight were not remarkably different from the original sample before exclusions (Table 1), with two minor exceptions. The BMI was somewhat higher in the older group in the original sample (26.1 kg/m<sup>2</sup> before exclusions vs 21.2 kg/m<sup>2</sup> in the current analysis, likely due to exclusion of persons with illness as reported in Methods), and income was lower in the original sample in both age groups (younger: 41.3 vs 52.5  $\times$  \$1000/year; older: 29.0 vs 37.5  $\times$  \$1000/year).

To assess dietary variety, we first categorized each reported energy-containing food and beverage into 1 of 17 food groups based primarily on consumption pattern (e.g., main and side dishes: meat-based vs mixed), and whether they were discretionary sources of intake (e.g., beverages high in sugar vs dairy; fruit or vegetables vs cakes and cookies, for example). See Appendix for a detailed list of the 17 food groups.

From these initial groupings, we derived six types of dietary variety scores: a) total dietary variety, or the total number of unique food and caloric beverage items consumed; b) food group variety, or the total number of unique nutritionally important food groups from which at least 1 item was consumed (fruit, vegetable, dairy, grain, and meat/protein groups, with a maximum score of 5); c) micronutrient-dense variety, or the total number of unique food and energy-containing beverage items consumed from foods that were important sources of protein or micronutrients (including fruit- and vegetable-based items, dairy products, grains, nuts, legumes, and mixed main and side dishes); d) micronutrient-weak variety, or the total number of unique food and beverage items consumed from foods that were poor sources of protein or micronutrients (including high-sugar beverages, noncaloric beverages with caloric condiments added, candy, cakes, other sweets, and condiments); e) energy-dense variety, or the total number of unique food items consumed from foods high in energy density (including cakes, candy, and other sweets; carbohydrate-based items with more than 10% energy from fat such as toast with spread; cereals; pancakes; French fries and other potato dishes; popcorn; and mixed main and side dishes); and f) energy-weak variety, or the total number of unique food items consumed from foods low in energy density (including fruit-based, vegetable-based, and legume-based items such as apples, fruit salad, green salads [including those with meat], dried beans, and tofu products).

We calculated dietary variety variables as the number of unique food items consumed in 2 days. We calculated nutrient intakes from foods (and excluding any supplements used) as the 2-day average, and micronutrient and protein intakes were expressed as a percentage of the Estimated

Average Requirements (EARs) based on the new Dietary Reference Intake publications (there is no EAR for calcium, and so instead we used an arbitrary 100% of the “Adequate Intake” as the cutoff for adequacy) (34–37). Protein requirement was expressed as body weight reported as grams per kilogram. Calculated nutritional inadequacy determined using the Recommended Daily Allowance (RDA) for protein and EAR values for micronutrients does not indicate nutritional inadequacy for individual participants (because individual requirements vary) but nevertheless does provide an indication of nutritional problems within populations (38). In addition, recommended folate intake is now greater than during the analyzed survey as a result of the folate fortification program.

### Statistical Analyses

We performed data analyses using SPSS statistical software (SPSS Inc., Cary, NC). We expressed group values as means  $\pm$  standard deviation for demographic variables and means  $\pm$  standard error of the mean for other parameters and generally adjusted them for sex differences within each age group. We tested demographic differences between younger and older participants using an independent samples *t* test, or, when it was necessary to adjust for sex, by using analysis of covariance. We used analysis of covariance, with adjustment for sex, to determine whether dietary variety and macronutrient intake differed according to age group and BMI group (see Results). In this analysis, we also tested potential interactions of age and BMI.

We used analysis of covariance to evaluate best-predicting models for BMI and energy intake by dietary variety and other variables. For this we used a step-wise backward procedure in which the main effects and two-way interactions of interest were initially tested (e.g., age group by dietary variety) and the interactions followed by main effects were subsequently removed from the model one at a time from higher to lower order terms if not significant.

Finally, based on our findings from these analyses, we evaluated differences in macronutrient intake between age groups according to high or low intake of micronutrient-dense variety using analysis of covariance, adjusting for sex and testing for any interaction between age and food variety. For this analysis, we categorized micronutrient-dense variety as either low or high based on the study sample's median micronutrient-dense variety value ( $\leq 12$  vs  $> 12$ ). We also calculated the percentage of persons in each age group who met EARs for 14 micronutrients (for the individual micronutrients and an average for 14 micronutrients) and determined whether this proportion differed by micronutrient-dense variety intake in the 2 age groups (and the age group by variety interaction) by using logistic regression analysis. For all analyses, probability values less than .05 were accepted as significant.

## RESULTS

Table 1 shows the characteristics of the younger (21 to 60 years) and older (61 to 90 years) participants. We evaluated

the 3 age groups in preliminary analyses (21–45 years, 46–60 years, and 61–90 years), but because no important differences emerged between the 2 younger groups, we combined them when we presented the data. As seen, the older participants had a lower mean BMI, lower family income, fewer years of education, and spent more time watching television.

We evaluated differences in reported dietary variety and macronutrient intakes between age groups before we considered the association of different dietary variety variables with energy and micronutrient intakes and BMI. In these analyses, we separated participants into three BMI levels. A BMI of 25 kg/m<sup>2</sup> defined the boundary between having a healthy weight and being overweight (39), and a BMI of 22 kg/m<sup>2</sup> defined the lower boundary of healthy weight. We defined low weight as a BMI less than 22 kg/m<sup>2</sup> (and, as noted previously, we excluded participants with a BMI less than 17 kg/m<sup>2</sup> from the analysis). Although there is no standard BMI definition for low weight in elderly persons, we used 22 kg/m<sup>2</sup> in this study because, among older persons, it provides the greatest sensitivity for predicting biochemical indicators of malnutrition (10), reduced ability to perform activities of daily living (4), and reduced functional status (40).

As shown in Table 2, total dietary variety, food group variety, energy-weak variety, and micronutrient-dense variety were all greater in the older participants compared with the younger ones, and micronutrient-weak variety was lower. In addition, we observed a significant interaction of age group and BMI such that older persons with low BMI consumed less energy-dense variety than did older persons with higher BMIs. In separate analyses (data not shown), total dietary variety and micronutrient-dense variety were positively predicted by education, age, and income; food group variety was positively predicted by education; energy-dense variety was predicted by sex; and energy-weak variety was predicted by education, age, income, and sex. Energy intake and protein intake as percentages of the RDA were significantly lower in older persons. In addition, a lower percentage of older persons achieved the RDA for protein, particularly in the low BMI group.

We conducted multiple regression analyses to further evaluate the associations among dietary variety, energy and protein intakes, and BMI. As summarized in Table 3, the best-fitting models for predicting energy intake and BMI from dietary variety included the energy-dense variety variable (adjusted  $R^2 = .574$  for energy), but total dietary variety was nearly as strong a predictor (adjusted  $R^2 = .569$  for energy, data not shown). Both energy-dense variety and energy intake predicted BMI in separate models, but no variety variable was significant in models including energy intake (indicating that, as would be expected, variety was associated with BMI through its association with energy intake). In addition, protein intake (either expressed as a percentage of RDA or a percentage of RDA for intakes less than the RDA and a value of 100% for intakes greater than the RDA) did not significantly predict BMI in models including energy intake. Figure 1 shows the partial correlation plots for best-fitting models predicting energy intake and BMI from energy-dense variety.

Table 2. Dietary Variety and Macronutrient Intakes of Healthy U.S. Men and Women, by Age Group and BMI (Mean  $\pm$  SEM)\*

Dietary Variables	Younger (21–60 Years)				Older (61–90 Years)			
	Total	<22	BMI 22–24.99	$\geq 25$	Total	<22	BMI 22–24.99	$\geq 25$
<i>N</i>	892	198	282	412	282	55	86	141
Variety variables								
Total variety <sup>†</sup>	17.4 $\pm$ 0.2	17.6 $\pm$ 0.3	17.3 $\pm$ 0.3	17.3 $\pm$ 0.2	18.1 $\pm$ 0.3	17.7 $\pm$ 0.6	18.1 $\pm$ 0.5	18.7 $\pm$ 0.4
Food group variety <sup>†</sup>	3.7 $\pm$ 0.0	3.8 $\pm$ 0.1	3.7 $\pm$ 0.1	3.7 $\pm$ 0.0	4.1 $\pm$ 0.1	4.0 $\pm$ 0.1	4.0 $\pm$ 0.1	4.1 $\pm$ 0.1
Energy-dense variety <sup>  ¶</sup>	9.5 $\pm$ 0.1	8.8 $\pm$ 0.3	9.6 $\pm$ 0.2	10.1 $\pm$ 0.2	9.0 $\pm$ 0.2	7.8 $\pm$ 0.5	8.9 $\pm$ 0.4	10.5 $\pm$ 0.3
Energy-weak variety <sup>‡§</sup>	2.5 $\pm$ 0.1	2.7 $\pm$ 0.1	2.4 $\pm$ 0.1	2.4 $\pm$ 0.1	3.6 $\pm$ 0.1	3.8 $\pm$ 0.3	3.8 $\pm$ 0.2	3.2 $\pm$ 0.2
Micronutrient-dense variety <sup>†</sup>	12.1 $\pm$ 0.1	12.2 $\pm$ 0.3	12.0 $\pm$ 0.2	12.0 $\pm$ 0.2	13.2 $\pm$ 0.2	12.8 $\pm$ 0.5	13.1 $\pm$ 0.4	13.6 $\pm$ 0.3
Micronutrient-weak variety <sup>†</sup>	5.3 $\pm$ 0.1	5.4 $\pm$ 0.2	5.3 $\pm$ 0.1	5.3 $\pm$ 0.1	5.0 $\pm$ 0.2	4.9 $\pm$ 0.3	4.9 $\pm$ 0.3	5.1 $\pm$ 0.2
Macronutrient variables								
Energy (kcal/d) <sup>  </sup>	2502 $\pm$ 16	2364 $\pm$ 33	2491 $\pm$ 27	2654 $\pm$ 23	1996 $\pm$ 29	1890 $\pm$ 61	1935 $\pm$ 48	2162 $\pm$ 38
Protein (% RDA) <sup>  </sup>	164 $\pm$ 2	155 $\pm$ 3	164 $\pm$ 3	174 $\pm$ 2	133 $\pm$ 3	125 $\pm$ 6	131 $\pm$ 5	143 $\pm$ 4
Protein (% participants meeting RDA) <sup>  ¶</sup>	96	90	98	98	86	75	88	89

Note: \*All values are adjusted for sex.

<sup>†</sup>Significant difference between age groups,  $p \leq .05$ .

<sup>‡</sup>Significant difference between age groups,  $p \leq .001$ .

<sup>§</sup>Significant difference between BMI groups,  $p \leq .05$ .

<sup>||</sup>Significant difference between BMI groups,  $p \leq .001$ .

<sup>¶</sup>Significant age group  $\times$  BMI interaction,  $p \leq .05$ .

BMI = body mass index; SEM = standard error of the mean; RDA = recommended dietary allowance.

We also evaluated the association between dietary variety and micronutrient intakes using Pearson correlation analyses. As summarized in Figure 2, micronutrient-dense variety positively predicted mean micronutrient intakes in both younger and older adults, but energy-dense variety did not, and in older adults it was negatively associated with mean micronutrient intakes. Therefore, we further analyzed the

Table 3. Best-Fit Models for Prediction of BMI and Energy Intake in Healthy U.S. Men and Women by Dietary Variety Scores

Regression Models	$\beta$ Coefficient	SE	Partial <i>r</i>	<i>p</i> Value	Model Adj. $R^2/p$
Energy intake prediction					0.574/<.001
Constant	-413.076	333.145		.215	
Age group (1 = younger, 2 = older)	-409.688	30.014	-0.372	<.001	
Height, cm	19.652	1.811	0.303	<.001	
Dietary fiber, g/1000 kcal	-11.330	4.008	-0.083	.005	
Energy-dense variety (no. of unique food items over 2 d)	31.724	3.484	0.258	<.001	
BMI prediction					0.124/<.001
Constant	31.173	2.880		<.001	
Sex (M = 0, F = 1)	-2.267	0.320	-0.203	<.001	
Height, cm	-0.046	0.015	-0.087	.003	
Physical inactivity (hrs TV/d)	0.167	0.063	0.077	.009	
Dietary fat, % energy	0.064	0.017	0.110	<.001	
Dietary fiber, g/1000 kcal	-0.115	0.036	-0.094	.001	
Energy-dense variety (no. of unique food items over 2 d)	0.118	0.032	0.109	<.001	

Note: SE = standard error; M = male; F = female; BMI = body mass index.

relationship between the adequacy of individual micronutrient intakes and micronutrient-dense variety by defining high and low micronutrient-dense variety groups as 12 or fewer or more than 12 unique foods consumed during the 2-day measurement period (12 is the number of foods that represents the median micronutrient-dense variety).

Table 4 shows energy, macronutrient, and protein intakes in relation to high or low micronutrient-dense variety. Energy and macronutrient intakes were lower in the older participants as a result of lower energy requirements and lower BMIs (Table 2). In general, older persons were less likely to meet EARs for individual nutrients (the percentage of older participants who met individual EARs was lower for vitamins E, niacin, riboflavin, B6, folate, calcium, magnesium, and zinc), and the percentage of older persons who met the EARs for all 14 micronutrients combined was also lower.

Consuming a wide variety of micronutrient-rich foods tended to counterbalance the reduced micronutrient intakes associated with old age, with positive associations of micronutrient-dense variety with intakes of vitamins A, E, C, folate, B12, magnesium, and zinc. The percentages of participants who consumed the RDA for protein and the EARs for micronutrients were particularly low among older persons who had low BMIs (<22 kg/m<sup>2</sup>) and low micronutrient-dense variety: only 65.4% for protein (compared with 97.6% for older adults who consumed a wide variety of micronutrient-dense foods and had a BMI  $\geq 22$  kg/m<sup>2</sup>) and 0.0% for the EARs for all 14 micronutrients (compared with 9.2% for older adults who consumed a wide variety of micronutrient-dense foods and had a BMI  $\geq 22$  kg/m<sup>2</sup>).

## DISCUSSION

The results of this study indicate that consumption of a diet containing a low variety of energy-dense foods is

associated with low energy intake and low BMI, and they may help to explain both unintentional weight loss and the maintenance of undesirably low body weight in old age. In addition, we found that older persons need to consume a *greater* variety of micronutrient-dense foods compared with younger adults to help maintain protein and micronutrient intakes. Taken together, these findings suggest that older persons need to receive advice on appropriate dietary variety to reduce the accelerated progression of disability and disease during late adult life associated with low body weight and micronutrient deficiencies (1,2,4–10,28–31).

In particular, this analysis of national dietary survey data shows, for the first time, that in the United States, community-dwelling elders with low BMIs consumed a lower variety of energy-dense foods frequently considered “unhealthy” or “fattening” and a greater variety of energy-weak foods considered “healthy” compared with older adults with higher BMIs. In addition, consumption of a low variety of energy-dense foods was associated with a markedly lower energy intake and lower BMI in statistical models controlling for confounding variables (and in the same models, the variety of energy-weak foods and protein intake were not significant predictors of energy intake or BMI).

Because the current study was cross-sectional, it is not possible to conclude, based solely on the analysis, that low dietary variety caused low energy intake and thus was responsible for weight loss. However, previous studies have shown a strong positive effect of variety among energy-dense foods on both energy intake and percentage of body fat (14–17,41) and a negative association between the variety of energy-weak foods consumed and percentage of body fat (16). Taken together, the results from the current study and previous research strongly suggest that consumption of a low variety of energy-dense foods and a wide variety of energy-weak foods in old age may contribute to low energy intake and maintenance of low BMI, and may also promote active weight loss.

Why older adults consume fewer energy-dense foods is not known and requires further study. In the current analysis, neither income nor education predicted dietary variety among energy-dense foods, suggesting that less education and low income are not associated with food choice among energy-dense foods. It is possible that impaired energy regulation in old age promotes reduced dietary variety among persons most severely affected, with the reduction in perceived hunger (42,43) decreasing the temptation to eat the energy-dense foods that are generally considered unhealthful (44). Consistent with this suggestion, one recent study reported that, in contrast to young adults, elderly persons fail to respond to a monotonous diet with cravings for different foods (45).

However, the fact that consumption of energy-weak foods was increased in old age at the same time that the variety of energy-dense foods was decreased suggests that other explanations may also have been important. Based on the fact that current national dietary guidelines (46) recommend that adults of all ages consume a variety of nutrient-dense foods, but make no recommendations on variety for other types of foods and give no guidance on changes in dietary variety with age, the older persons in this study may simply

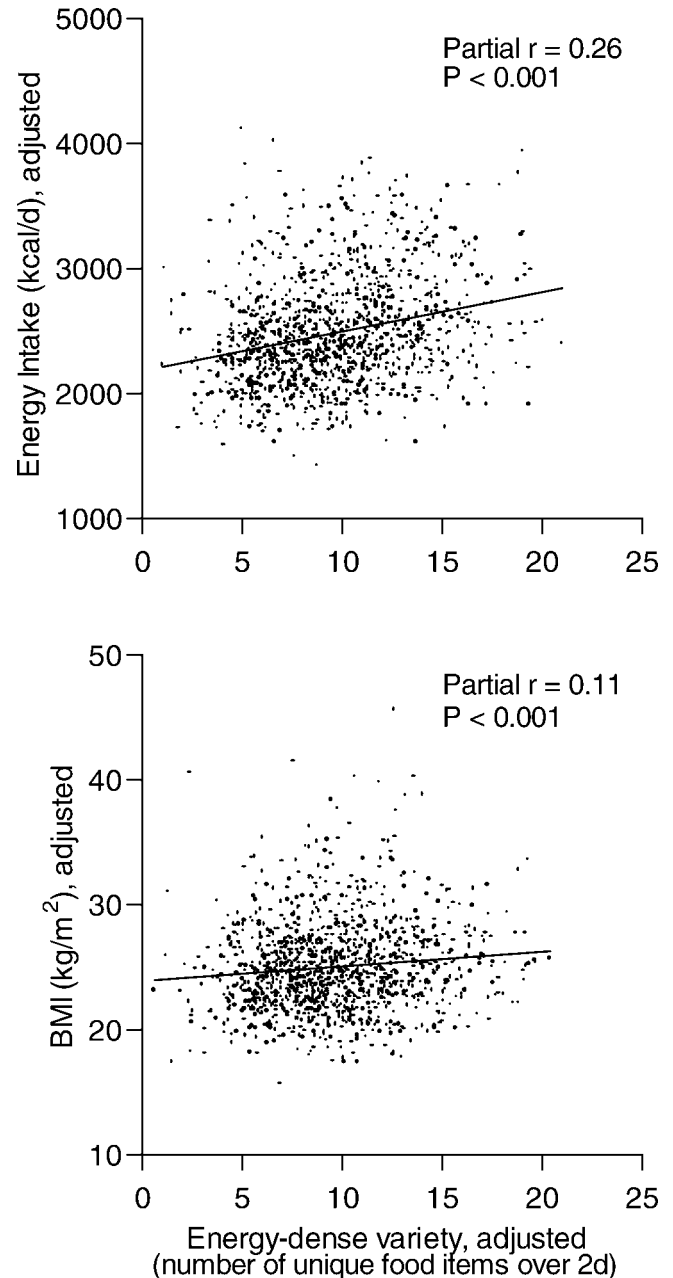


Figure 1. Energy-dense variety is shown in relation to energy intake and body mass index (BMI), adjusted for the confounding factors listed in Table 3. Energy-dense variety is defined as the number of unique energy-dense food items consumed during a period of 2 days.

have been following the current dietary guidelines more closely than were younger adults. Among older adults with low BMI or high risk for weight loss, more specific dietary advice encouraging variety among energy-dense foods may be beneficial.

Our study also provided information relevant to the common problem of protein and micronutrient deficiencies in old age (23–26), in particular addressing the question of whether certain classes of dietary variety need to change to maintain protein and micronutrient status. Previous studies

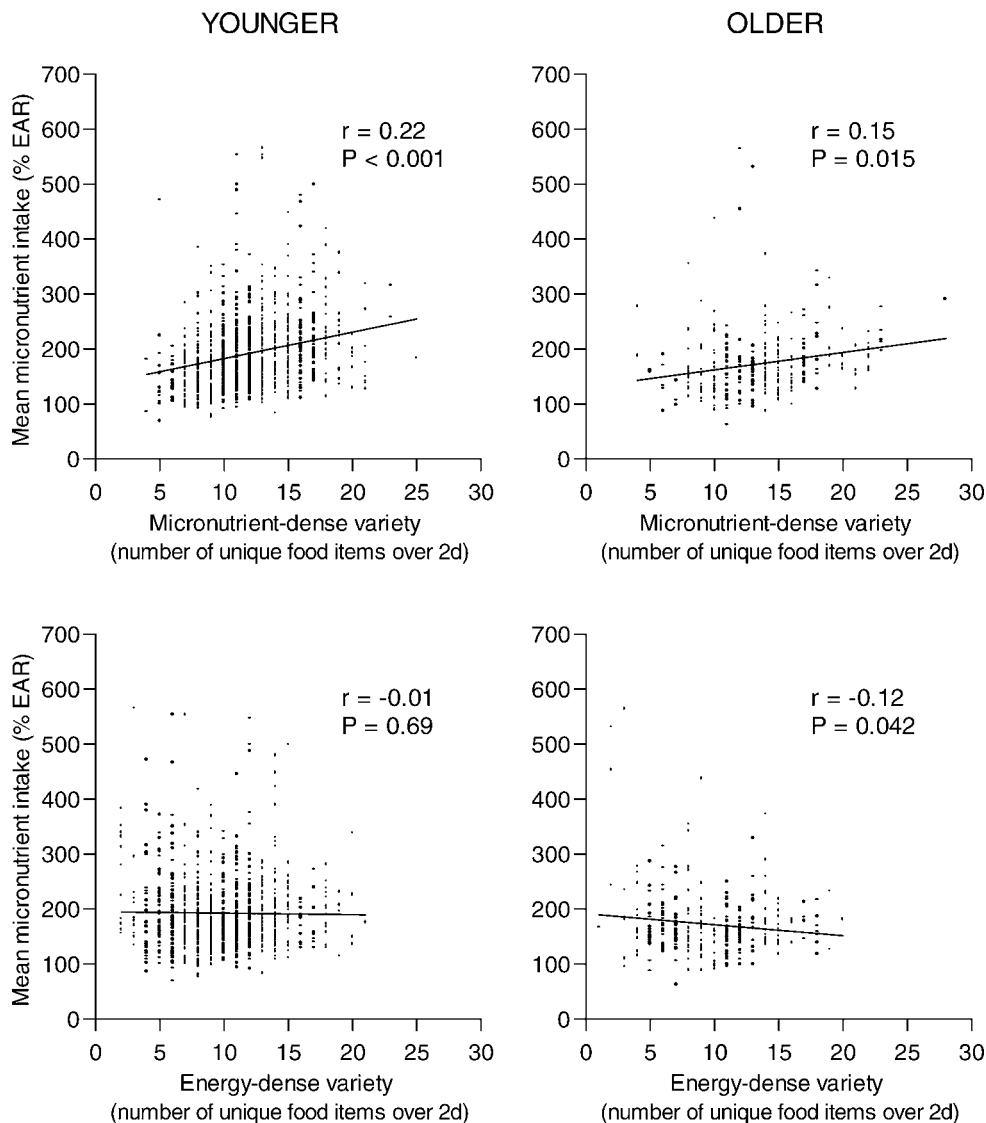


Figure 2. Micronutrient-dense variety and energy-dense variety are shown in relation to mean micronutrient intake (expressed as a mean percentage of estimated average requirements [EARs]) for all 14 micronutrients in younger and older persons). Micronutrient-dense variety and energy-dense variety are defined as the number of unique micronutrient-dense food items and the number of energy-dense food items consumed during a period of 2 days.

have suggested that low dietary variety in old age is associated with low intake of micronutrients (20,23), but how these levels of variety compare with those consumed by younger adults was uncertain because they had no young control participants. Furthermore, the results were probably confounded by the inclusion of physiologically impossible dietary records (22). In the current analyses, which excluded data from persons with implausible values for energy intake using previously validated techniques (22), the number of different food groups consumed and the variety of micronutrient-dense and energy-weak foods consumed were greater in older adults than in younger adults, while at the same time the variety of micronutrient-weak foods was lower.

These differences seen between the age groups helped counterbalance the substantial decrease in micronutrient intake in the older group that would have otherwise occurred

as a result of reduced energy intake (because micronutrient intake parallels total food intake). However, only among older adults consuming a high variety of micronutrient-dense foods was micronutrient adequacy maintained at levels approaching those seen in younger persons consuming a lower variety of micronutrient-dense foods.

Nutritional risk was particularly high among older adults consuming a low variety of micronutrient-dense foods and also having low BMIs, with only 65.4% meeting the RDA for protein and none meeting the EAR for all 14 nutrients. (Although nutrient intake may have been underestimated due to lack of sufficient number of days in the survey to account for the normal and expected day-to-day variation in nutrient intake, any potential underestimation was likely similar between the age groups.) These results indicate that the variety of micronutrient-dense foods consumed in late

Table 4. Macronutrient Intake (Mean  $\pm$  SEM)\* and Percentage of Participants Achieving Micronutrient Adequacy in Healthy U.S. Men and Women by Age Group, Total, and According to Micronutrient-Dense Variety Consumption

Dietary Variables	Younger (21–60 Years)			Older (61–90 Years)		
	Total	Micronutrient-Dense Variety (No. of Items/2 d)		Total	Micronutrient-Dense Variety (No. of Items/2 d)	
		$\leq 12$	$> 12$		$\leq 12$	$> 12$
<i>N</i>	892	522	370	282	121	161
<b>Macronutrient intake</b>						
Energy, kcal/d <sup>†‡</sup>	2531 $\pm$ 16	2504 $\pm$ 20	2568 $\pm$ 24	2034 $\pm$ 28	1949 $\pm$ 42	2098 $\pm$ 36
Fat, % energy	34 $\pm$ 0.2	34.0 $\pm$ 0.3	33.9 $\pm$ 0.4	33.7 $\pm$ 0.4	33.3 $\pm$ 0.6	34.1 $\pm$ 0.6
Carbohydrate, % energy <sup>†</sup>	50.1 $\pm$ 0.3	50.6 $\pm$ 0.4	49.5 $\pm$ 0.4	50.8 $\pm$ 0.5	51.7 $\pm$ 0.8	50.1 $\pm$ 0.7
Protein, %RDA <sup>†‡</sup>	166 $\pm$ 1	158 $\pm$ 2	177 $\pm$ 2	136 $\pm$ 3	126 $\pm$ 4	143 $\pm$ 3
Fiber, g/1000 kcal <sup>†‡</sup>	8.0 $\pm$ 0.1	7.4 $\pm$ 0.1	8.7 $\pm$ 0.2	9.4 $\pm$ 0.3	8.9 $\pm$ 0.3	9.8 $\pm$ 0.3
<b>Micronutrient intake</b> (% participants achieving EAR)						
Vitamin A <sup>†</sup>	78.0	69.9	89.5	82.6	76.0	87.6
Vitamin E <sup>†‡</sup>	30.9	27.6	35.7	19.5	12.4	24.8
Vitamin C <sup>†</sup>	62.8	55.2	73.5	67.4	58.7	73.9
Thiamin <sup>†</sup>	98.3	97.9	98.9	95.4	93.4	96.0
Riboflavin	99.1	98.5	100.0	98.2	97.5	98.8
Niacin <sup>†</sup>	99.4	99.2	99.7	96.1	93.4	98.1
Vitamin B6 <sup>†‡</sup>	92.7	90.2	96.2	83.0	73.6	90.1
Folate <sup>†‡</sup>	39.5	33.5	47.0	30.9	24.0	36.0
Vitamin B12 <sup>†</sup>	92.0	91.4	93.0	90.4	86.8	93.2
Iron	99.7	99.6	99.7	99.6	99.2	100.0
Calcium <sup>†</sup>	34.8	33.9	35.9	13.5	12.4	14.3
Phosphorus	99.9	99.8	100.0	99.3	98.3	100.0
Magnesium <sup>†‡</sup>	58.6	51.3	68.9	42.2	28.9	52.2
Zinc <sup>†‡</sup>	91.9	90.4	94.1	81.6	76.0	85.7
100% of EAR for 14 micronutrients <sup>†‡</sup>	8.4	6.7	10.8	3.5	1.7	5.0

Note: \*All values are adjusted for sex.

<sup>†</sup>Significant effect of age group,  $p = .001-.05$ .

<sup>‡</sup>Significant effect of variety group,  $p = .001-.05$ .

SEM = standard error of mean; RDA = recommended daily allowance; EAR = estimated average requirements.

adult life is very important, particularly for adults with low BMI, and that micronutrient-dense variety actually needs to increase in old age to preserve nutritional health unless multivitamin and mineral supplements are used routinely (47). This observation further emphasizes the need for age-specific guidelines on appropriate dietary variety, with emphasis on variety among micronutrient-dense foods for all older adults, and on variety among foods that are both micronutrient-dense and energy-dense for persons at risk for weight loss or who have low BMI.

### Conclusion

In contrast to previous suggestions that older persons consume a monotonous diet, we found that adults who were 61 years or older consumed a wider total food variety and a greater variety of micronutrient-dense and energy-weak foods than did adults who were 60 years or younger. Furthermore, the results of this study suggest for the first time that patterns of dietary variety are especially important in old age to prevent increased nutritional risk, and in particular that consumption of a low variety of energy-dense and micronutrient-dense foods in old age should be avoided because it

predicts low energy, protein, and micronutrient intakes and low BMI even in apparently healthy elderly persons.

Although inadequate dietary variety is probably only one of several factors that reduce nutrient intakes in old age, the absence of national guidelines on what constitutes healthful dietary variety at different ages, and the focus on fruit and vegetable variety for all ages, has probably led to widespread misperceptions about what constitutes a healthful balance of variety among different types of foods in old age. Patient education could make an important contribution to reducing the accelerated morbidity and mortality rates associated with weight loss and nutritional deficiencies in late adult life.

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## APPENDIX

*Initial Food Groups Used To Score Dietary Variety*

No.	Name of Group	Examples
1	Fruit and fruit-based (nondessert)	Apple, fruit salad
2	Vegetable and vegetable-based (not potato)	Broccoli, salad, salads with meat (except taco salad)
3	Beverages: caloric/discretionary	Soda, lemonade, alcohol, presweetened iced tea, chocolate milk, juices
4	Beverages: caloric/dairy (no chocolate milk)	Skim milk, 1% milk, 2% milk, whole milk, powdered milk, soy milk, rice beverage
5	Beverages: noncaloric only, or noncaloric with noncaloric sweetener	Tea, tea with lemon, coffee with artificial sweetener
6	Beverages: noncaloric with caloric condiment	Tea with milk, coffee with cream and sugar
7	Cakes, cookies, pastries, quick breads, muffins, pie	Carrot cake, Oreo cookie, cinnamon roll, banana bread, blueberry muffin, doughnut, cheesecake
8	Liquid sweets	Vanilla ice cream, frozen yogurt, gelato, kefir, flavored ice bars, ice cream bars
9	Candy	Chocolate bars, hard candies, gummy candies
10	Carbohydrates	Bread, toast with any spread, cereal, cereal with fruit and milk/sugar, oatmeal, pancakes w/maple syrup, French fries, stuffing, rice, potatoes, pretzels, chips, popcorn, party mix, crackers, grits, meal replacement bars
11	Main or side dishes: meat/fish/poultry and m/f/p-based	Steak, sausage, bacon, chicken fried steak
12	Main or side dishes: egg and egg-based	Scrambled eggs, fried eggs, omelets, quiche, fritatta, souffle
13	Main or side dishes: mixed	Sandwiches, burgers, pizza, tacos, burritos, casseroles, stew, pasta dishes, taco salad
14	Main or side dishes: cream soups and broth-based soups	New England clam chowder, cream of tomato, cream of mushroom, minestrone, chicken noodle, Manhattan clam chowder
15	Main or side: dairy	Yogurt, cottage cheese, other cheese
16	Legumes	Tofu and tofu-products (not liquid), black beans, refried beans
17	Nuts: eaten alone	Peanuts, cashews, almonds
18	Condiments: eaten alone	Relish, pickles, pickled veggies, catsup, salsa, dip, jam/jelly, butter, margarine, salad dressing, sugar, sweetener, chocolate syrup, garlic