Dietary Variety Increases the Probability of Nutrient Adequacy among Adults[1]

Janet A. Foote, Suzanne P. Murphy,[2] Lynne R. Wilkens, P. Peter Basiotis,* and Andrea Carlson*

*Cancer Research Center of Hawaii, University of Hawaii and *U.S. Department of Agriculture, Center for Nutrition Policy and Promotion, Alexandria, VA*

ABSTRACT Despite guidance to consume a variety of foods, the role of dietary variety in ensuring nutrient adequacy is unclear. The aim of this study was to determine whether a commodity-based measure of dietary variety was associated with the probability of nutrient adequacy after adjusting for energy and food group intakes. Subjects were 4969 men and 4800 women ≥ 19 y old who participated in the Continuing Survey of Food Intakes for Individuals 1994–1996. Using 24-h recall data, the mean probability of adequacy across 15 nutrients was calculated using the Dietary Reference Intakes. Dietary variety was defined using a commodity-based method similar to that used for the Healthy Eating Index (HEI). Associations were examined in gender-specific multivariate regression models. Energy intake was a strong predictor of the mean probability of adequacy in models controlled for age, BMI, education level, and ethnicity (model $R^2 = 0.60$ and 0.54 for men and women, respectively). Adding the number of servings from each of the 5 Food Guide Pyramid (FGP) groups to the models significantly improved the model fit ($R^2 = 0.69$ and 0.66 for men and women). Adding dietary variety again significantly improved the model fit for both men and women ($R^2 = 0.73$ and 0.70, respectively). Variety counts within the dairy and grain groups were most strongly associated with improved nutrient adequacy. Dietary variety as defined by the HEI contributes an additional component of dietary quality that is not captured by FGP servings or energy intake. J. Nutr. 134: 1779–1785, 2004.

KEY WORDS: • *dietary variety* • *nutrient adequacy* • *food group servings* • *CSFII 1994–1996*

The Dietary Guidelines for Americans have been issued every 5 years beginning in 1980, and the first 4 editions all contained a guideline advising consumers to "Eat a variety of foods." The concept of variety is also a cornerstone of the Food Guide Pyramid (FGP),[3] along with proportionality and moderation (1). However, the Dietary Guidelines Advisory Committee (DGAC) for the year 2000 edition of the guidelines replaced the traditional variety guideline with one suggesting, "Let the Pyramid guide your food choices" (2). This change was driven by 3 types of evidence: *1*) although it was clear that choosing foods appropriately across the Pyramid food groups (between-group variety) contributed to improved nutrient adequacy, there was very little evidence to support a similar role for within-group variety (3); *2*) advice to consume a variety of foods might encourage overconsumption of energy, and thus contribute to the prevalence of obesity in the United States (4); and *3*) focus group respondents indicated considerable confusion about the definition of "variety" and many believed that foods of low nutrient density, such as sweets and desserts, could be viewed as contributing to dietary variety (5). Although the variety guideline did not appear in the 2000 Dietary Guidelines, advice regarding variety was still present, in both the fruit and vegetable guideline ("Choose a variety of fruits and vegetables daily") and the grain guideline ("Choose a variety of grains daily, especially whole grains") (2).

The term "dietary variety" is inconsistently defined by different researchers (6). The unit that is counted toward variety can consist of food codes, food groups, or food ingredients (determined after all mixtures are decomposed) that are reported by a subject. Methods of counting dietary variety for a specified time period (usually 1–3 d) include the number of unique food groups reported (*between-group variety*), the number of unique foods within various food groups reported (*within-group variety*), and the total number of unique foods reported (*total dietary variety*). Most measures of dietary variety require some minimum portion size for a food to contribute to the dietary variety count. These differing definitions have led to conflicting results regarding the role of dietary variety in a healthy diet.

The year 2000 DGAC also noted the paucity of research on the role of dietary variety in contributing to nutrient adequacy, and to the overall quality of the diet. One of the committee's recommendations was, "associations among variety, energy intake, nutrient adequacy, and health outcomes

[1] Supported by cooperative agreement USDA 43–3AEM-1–80082 from the Economic Research Service of the U.S. Department of Agriculture.

[2] To whom correspondence should be addressed.
E-mail: suzanne@crch.hawaii.edu.

[3] Abbreviations used: AI, Adequate Intake; CSFII, Continuing Survey of Food Intakes for Individuals; DGAC, Dietary Guidelines Advisory Committee; DRI, Dietary Reference Intake; EAR, Estimated Average Requirement; FGP, Food Guide Pyramid; HEI, Healthy Eating Index; RDA, Recommended Dietary Allowance.

Manuscript received 21 January 2004. Initial review completed 10 March 2004. Revision accepted 5 April 2004.

should be evaluated thoroughly" (2). Furthermore, the committee noted that a clear definition of dietary variety is needed in order to guide consumers to take specific actions. To address these needs, we used a commodity-based definition of dietary variety, similar to the one used in the Healthy Eating Index (HEI) (7), to examine predictors of nutrient adequacy for adults who participated in the 1994–1996 Continuing Survey of Food Intakes by Individuals (CSFII).

SUBJECTS AND METHODS

CSFII 1994–1996. The 1994–1996 Continuing Survey of Food Intakes by Individuals (CSFII 94–96), conducted by the USDA, collected information on food and nutrient intakes for a representative sample of individuals living in the conterminous 48 states and the District of Columbia (8,9). The USDA provides public use data files containing the following data for each CSFII participant: demographic variables, intakes of macro- and micronutrients, and servings of FGP food groups (10). Details of the survey design were published previously (8). CSFII 94–96 collected 2 d of dietary data using an in-person, multipass 24-h recall methodology. However, both recall days are not available for the full sample. We therefore choose to use only d 1 of dietary data to ensure a broader representation of the population. A brief examination of 1- vs. 2-d measures indicated few differences if we had chosen a 2-d time frame. We excluded participants with intakes < 2.09 MJ/d (500 kcal/d; $n = 118$) and >20.9 MJ/d (5000 kcal/d; $n = 132$) as being atypical for the purposes of the study. After these exclusions, dietary data for 1 d were available for 9769 adults ≥ 19 y old, including 4969 men and 4800 women.

Probability of adequacy. The probability that a given nutrient intake is adequate for an individual can be calculated if the requirement distribution is known. If this distribution is approximately normal, it is defined by the Estimated Average Requirement (EAR) and its SD (11–15). Using this distribution, the "probnorm" function in SAS (16) can be used to calculate the probability of adequacy for a specific intake as the proportion of the population with a requirement that is less than that intake. The resulting values for probability of adequacy range, by definition, from 0 to 100%. The probability of adequacy for each CSFII 94–96 participant was calculated using the probnorm function for 13 nutrients (vitamins A, C, E, B-6, B-12, thiamin, riboflavin, niacin, folate, phosphorus, magnesium, copper, and zinc). The requirement distribution for iron is skewed, and it was necessary to use published tables giving the probability of adequacy for specific intake ranges (15). It not necessary to adjust intakes for the effect of day-to-day variation when computing the probability of adequacy for an individual on a single day, although this adjustment is required to accurately estimate the prevalence of inadequacy for usual intakes within a population (14).

Calcium is a nutrient of public health concern (11) for which no EAR is available. An Adequate Intake (AI) has been set (11), but no SD has been specified. To include an evaluation of calcium intake in our analyses, we compared intake levels to the AI. The probability of adequacy was defined for calcium as follows: 0% for calcium intakes ≤ one fourth of the AI, 25% for calcium intakes > one fourth AI and ≤ one half AI, 50% for calcium intakes > one half AI and ≤ three fourths AI, 75% for calcium intakes > three fourths AI and ≤ AI, and 100% for calcium intakes above the AI. For example, the AI for calcium is 1000 mg/d for men and women 19–30 y old; intakes between 0 and 250 mg/d would be given a 0% probability of adequacy, those between 251 and 500 mg/d would be given 25%, those between 501 and 750 mg/d would be given 50%, those between 751 and 1000 mg/d would be assigned 75%, and those >1000 mg/d would be assigned 100%. For each subject, the probabilities of adequacy for the selected 15 micronutrients were summed and divided by 15 to create a mean probability of adequacy.

Determination of dietary variety. A database that disaggregates mixtures was developed by the USDA for use in calculating the servings of FGP food groups. Each ingredient in a complex food can thus be assigned to the appropriate FGP group (10). Variations in nutrient concentrations due to changes in moisture content are reflected in the number of servings/100 g. Dietary variety was defined as the number of food variety groups reported in the 24-h recall. The USDA disaggregated database provided the structure for assigning variety codes to each basic food or ingredient during the development of the HEI (17,18). The general approach was to assign foods within an agricultural commodity type and with a similar vitamin and mineral profile to the same variety code. Differences in discretionary components (fat and sugar) did not cause a food to have a different variety code. Thus, in practice, this methodology assigns unique variety codes to basic food commodities (e.g., milk, beef, wheat, potatoes, apricots), but not to different preparations of these ingredients (e.g., pudding, hamburger, muffins, potato chips, dried apricots). For consistency with the FGP food groups, some exceptions were made, i.e, organ meats and luncheon meats were coded into separate variety categories; cow's milk, cheese, and yogurt received different variety codes; and whole grains were separated from refined grains.

The dietary variety database that was used to calculate the HEI variety variable was recently updated so that each variety code could be assigned to specific FGP food groups. We further revised the database for use in this analysis, by reducing the number of variety codes from 349 to 293. The most substantial reduction was in the variety coding of non-whole-grain foods in which several refined wheat grain items were combined to avoid separate dietary variety codes for foods that differed primarily in fat or sugar content. In contrast, all legumes were assigned a single variety code in the original database, but different codes were used on the revised file to identify various types of legumes. After these changes had been made and checked, total dietary variety and variety within each of the 5 main FGP food groups was computed for d 1 of the intake data for each adult in the CSFII.

In the HEI approach, a minimum of one half of a food serving of an item must have been consumed during the 24-h time period for the food to count toward dietary variety. A preliminary analysis modifying the necessary daily serving of one half to one fourth for the food item to contribute toward variety had little effect on the dietary variety scores. Thus, we continued to use the minimum of one half of a serving when calculating dietary variety.

Statistical analyses. The CSFII data were analyzed using SAS software (version 8.2) (16) and SUDAAN (19) to adjust appropriately for the survey design and the sampling weights. χ^2 tests were used to assess the gender differences in the distribution of characteristics, and Spearman's correlations were used to assess the association of FGP servings and dietary variety with the mean probability of adequacy, with and without adjustment for energy. Because SUDAAN does not have a correlation procedure, Spearman's correlations were computed as the slope of the regression of the standardized ranks for the mean probability of adequacy on the standardized ranks for the number of FGP servings or the dietary variety count. Spearman's correlations were used instead of Pearson's correlations because some of the variables used as independent variables in the regression, such as the FGP servings, were not normally distributed. Linear regression models were fit to assess how well independent variables explained the variability in the mean probability of nutrient adequacy. Base models were initially fit using the following independent variables: age, education level, BMI, ethnicity, and energy. The 5 variables for the servings of the FGP groups were included in the model, and then a variable for total variety was added. Last, the total variety score was replaced by within-FGP group variety counts. Separate models were fit by gender. Change in R^2 values was used to assess the improvement in fit at each model-building step. The effect or combined effect of variable(s) in the regression models was examined using contrast statements to compute an adjusted Wald statistic (20). A significance level of 0.05 was used for all analyses.

RESULTS

Among this survey population, 77% of the adults were Caucasian, 11% African American, and 9% Hispanic (**Table 1**). The mean age of the adults was slightly >49 y, and almost 80% had at least a high school education. In general, the demographic characteristics of this adult population did not differ substantially by gender. However, based on self-reported heights and weights, proportionately more men than women

TABLE 1

Demographic characteristics among CSFII 1994–1996 adult men and women[1]

	Men (*n* = 4969)	Women (*n* = 4800)
Ethnicity, *n (%)*		
Non-Hispanic Caucasian	3866 (77.8)	3609 (75.2)
Non-Hispanic African American	486 (9.8)	599 (12.5)
Hispanic	445 (9.0)	421 (8.8)
Asian/Pacific Islander	116 (2.3)	114 (2.4)
American Indian	26 (0.5)	29 (0.6)
Other	30 (0.6)	28 (0.6)
Age,[2] *y*	49.7 ± 17.8	49.2 ± 17.8
Age group, *n (%)*		
19–30 y	853 (17.2)	866 (18.0)
31–50 y	1747 (35.2)	1706 (35.5)
51–70 y	1658 (33.4)	1572 (32.8)
71 y+	711 (14.3)	656 (13.7)
Education, *n (%)*		
<High school	1032 (20.8)	1014 (21.1)
High school graduate	1621 (32.6)	1699 (35.4)
Some post-high school	994 (20.0)	1027 (21.4)
College graduate	579 (11.7)	507 (10.6)
Graduate school	658 (13.2)	484 (10.1)
No response	85 (1.7)	69 (1.4)
Household incomes according to Federal poverty level,[3] *n (%)*		
<131%	1033 (20.8)	1213 (25.3)
131–350%	1976 (39.8)	1899 (39.6)
>350%	1960 (39.4)	1688 (35.2)
BMI category, *n (%)*		
Normal (<25.0 kg/m^2)	1918 (38.6)	2350 (49.0)
Overweight (25.0–29.9 kg/m^2)	2138 (43.0)	1328 (27.7)
Obese (>30.0 kg/m^2)	913 (18.4)	1122 (23.4)

[1] All analyses were adjusted for sample weights and the clustered survey design.

[2] Values are means ± SD.

[3] The U.S. Census Bureau poverty thresholds for 1996 (adjusted for household size) were used to determine the poverty level for CSFII 94–96 participants.

were overweight (43 vs. 28%, respectively), whereas a greater proportion of the women were obese (23% of the women vs. 18% of the men).

Mean nutrient intakes and probabilities of adequacy were similar for CSFII men and women (**Table 2**). Among adult men, the mean probability of adequacy was <50% for vitamin A, vitamin C, vitamin E, folate, and magnesium. These results held for adult women, although the mean probability of adequacy for vitamin C was slightly >50%. Using the AI to estimate the probability of adequacy for calcium, the mean probability score was 59% in men and 46% in women. The mean probability of adequacy across 14 selected nutrients was 67% for men and 59% for women. Although the probability of adequate calcium intake was computed differently from the other nutrients, including the calcium score in the probability of adequacy index essentially did not alter the mean for either gender group. Therefore, we used the mean probability across all 15 nutrients, including calcium, in our analyses.

The mean FGP servings varied little by gender (**Table 3**). Mean dietary variety counts within each of the 5 primary FGP food groups, as well as total dietary variety across all the groups, were also similar among the CSFII men and women. Men reported consumption of 1.5 dairy servings, whereas women reported 1.2 servings. The variety score for dairy indicates that the dairy servings were usually from a single type of dairy product for both men and women, because the mean variety count was 0.9 for men and 0.8 for women.

Regardless of gender, 1.5 servings of fruit were consumed and like dairy, the variety of the fruit indicates the servings consumed were from a single source. Men reported consumption of almost 1 vegetable serving more than women; half of the additional serving could be attributed to a greater intake of white potatoes. Participants of both genders reported consuming ~2 different types of vegetables in the 24-h period. Men reported consumption of 2 more grain servings than women; ~1 serving of the grains consumed was from whole-grain sources, regardless of gender. Men consumed 1 more meat or protein serving than women. For both men and women, the servings from the meat/protein group were, on average, from ~2 different varieties. Overall, total dietary variety was not substantially different between the men (8.0 different foods/d) and women (7.3 different foods/d).

As would be expected, energy intake alone was highly correlated with the mean probability of adequacy (Spearman correlation $\rho = 0.7$, $P < 0.0001$) (**Table 4**). Energy intake was also significantly correlated with food group intakes, as well as with the dietary variety counts (data not shown). Thus, we present the correlations in Table 4 both unadjusted and adjusted for energy intake. As expected, in all cases, the energy-adjusted correlations were lower. The adjusted correlations between FGP servings and the mean probability of adequacy ranged from 0.03 to 0.26 for men, and from 0.07 to 0.30 for women. The highest correlations were for the dairy and fruit groups, for both men and women. Adjusted correlations between within-group variety counts and the mean probability of adequacy ranged from 0.03 to 0.24 for men and 0.06 to 0.26 for women. The magnitude of the correlations was similar for all of the food groups except meat/protein variety, which was substantially lower. Total dietary variety was better correlated with the mean probability of adequacy ($r = 0.44$ and 0.46 for men and women) than any of the within-group variety counts.

The independent effects of the variables were examined in multivariate linear regression models of the probability of adequacy score (**Table 5**). Demographic characteristics alone accounted for <4% of the variability in the mean probability of adequacy ($R^2 = 0.04$, $P < 0.0001$ for both men and women). Including energy intake along with the demographic characteristics substantially increased the percentage of variance explained, to 60 and 54% among men and women, respectively. The addition of FGP servings also significantly improved the explanatory ability of the models, to 69% for men and 66% for women. Servings of dairy foods were the most important predictors among the FGP variables for both men and women. When total dietary variety was added to the model, the percentage of variance explained once again improved significantly, to 73% for men and 70% for women. With total variety in the models, the coefficients for FGP servings decreased for most food groups, and dairy servings remained the highest. To evaluate the importance of variety within each of the food groups, we reanalyzed the models including the 5 within-group variables instead of the total variety variable. As expected, there was almost no difference in the explanatory power of the overall model, but dairy and grain variety contributed the most to the mean probability of adequacy, whereas vegetable and meat/protein variety contributed the least. However, all of the regression coefficients for the variety variables were significant ($P < 0.0001$).

We further examined the effect of within-group variety on nutrient adequacy by evaluating energy-adjusted correlations with specific nutrient adequacy variables, rather than the mean adequacy across all nutrients. The food groups with the

TABLE 2

Intakes and probability of adequacy for selected nutrients on the first 24-h recall day among adult CSFII participants[1]

	Men (*n* = 4969)		Women (*n* = 4800)	
	Nutrient[2]	Probability of adequacy[3]	Nutrient[2]	Probability of adequacy[3]
Energy, *kcal*	2350 ± 19.5	NA	1667 ± 11.6	NA
MJ	9.83 ± 0.08	NA	6.97 ± 0.05	NA
Vitamin A,[4] *RAE*	842 ± 30.1	47.0	679 ± 16.3	48.1
Vitamin C, *mg*	106 ± 1.9	49.3	91.4 ± 1.8	52.3
Vitamin E,[5] *mg* α*TE*	9.5 ± 0.1	14.1	7.2 ± 0.1	6.8
Thiamin, *mg*	1.9 ± 0.02	83.9	1.3 ± 0.01	72.2
Riboflavin, *mg*	2.2 ± 0.02	85.8	1.6 ± 0.01	80.9
Niacin, *mg*	27.0 ± 0.3	90.5	18.8 ± 0.2	80.4
Folate,[6] μg	293 ± 4.0	33.9	228 ± 2.6	20.9
Vitamin B-6, *mg*	2.1 ± 0.02	78.3	1.5 ± 0.01	60.7
Vitamin B-12, μg	6.2 ± 0.3	80.5	4.2 ± 0.1	64.2
Phosphorus, *mg*	1423 ± 11.8	94.3	1029 ± 7.8	85.1
Magnesium, *mg*	315 ± 3.2	36.1	236 ± 2.2	34.3
Iron, *mg*	17.8 ± 0.2	95.5	13.0 ± 0.1	79.4
Copper, *mg*	1.4 ± 0.02	87.4	1.1 ± 0.01	73.3
Zinc, *mg*	13.3 ± 0.2	65.7	9.2 ± 0.1	62.0
Calcium,[7] *mg*	854 ± 9.5	58.6	652 ± 7.7	45.7
Mean probability of adequacy (14 nutrients, excluding calcium)		67.3		58.6
Mean probability of adequacy (15 nutrients, including calcium)		66.7		57.7

1 All analyses were adjusted for sample weights and the clustered survey design.
2 Values are means ± SEM.
3 Values are mean percentages.
4 Retinol activity equivalents (RAE) were calculated by dividing vitamin A intake from carotenoids (in retinol equivalents) by 2.
5 Vitamin E intake in α-tocopherol equivalents (αTE) was multiplied by 80% to approximate intake from α-tocopherol alone as recommended by the Institute of Medicine. The DRI is based only on α-tocopherol and ~80% of the αTE in food is comprised of α-tocopherol.
6 Folate intake was not adjusted to reflect a higher availability of fortification folate; thus, intakes in dietary folate equivalents (DFE) are underestimated, as is the probability of adequacy.
7 The probability of adequacy for calcium was estimated using quartiles of the AI: 0% for calcium intakes $<$ one-fourth AI, 25% for calcium intakes $>$ one-fourth AI and $<$ one-half AI, 50% for calcium intakes $>$ one-half AI and $<$ three-fourths AI, 75% for calcium intakes $>$ three-fourths AI and $<$ AI, and 100% for calcium intakes above the AI.

strongest associations between within-group variety and mean probability of adequacy in Table 5 (dairy, grains, and fruit) were also significantly correlated with one or more of the at-risk nutrients listed in Table 2. Dairy variety was strongly associated with calcium adequacy ($\rho = 0.67$ for men and 0.70 for women), and also with vitamin A adequacy ($\rho = 0.29$ and 0.27, respectively). A variety of grains was associated with improved intakes of folate and magnesium, both nutrients with a low mean probability of adequacy. Fruit variety improved intakes of vitamins C and A, whereas associations between vegetable variety and these 2 nutrients were weaker. Meat variety had few associations with the at-risk nutrients. Vitamin E was the nutrient with the lowest probability of adequacy for this population, and total dietary variety was not strongly associated with greater adequacy ($\rho = 0.14$ for men and 0.08 for women).

DISCUSSION

This examination of the association of dietary variety and nutrient adequacy utilized the new Dietary Reference Intakes (DRIs) to construct a mean probability of nutrient adequacy for each adult participant in the CSFII 94–96. For the first time, it is possible to use nutrient intake standards for the United States to estimate the probability that the intakes of an individual are adequate, because the requirement distribution is now defined for most vitamins and minerals (14). Conceptually, the mean probability of adequacy is similar to the Mean Adequacy Ratio that was used with the former Recommended Dietary Allowances (RDAs) (21), but the probability values are more physiologically meaningful than ratios of intakes to the RDA.

Given the importance of adequate calcium in the diet and concern about low intakes among adults, we believe that any composite nutrient adequacy score must include calcium. Although it is not possible to calculate a true probability of adequacy for a nutrient with an AI, we have computed a calcium score, primarily as a method of ranking the adequacy of intakes. The resulting score fell within the expected range for a nutrient with problematic intakes, i.e., 59 for men and 46 for women. When the score was incorporated into the mean probability of adequacy, it had little effect on the overall mean. However, including calcium in the average did have the effect of highlighting the importance of dairy products in ensuring nutrient adequacy. This food group, measured as either servings or as a variety count, was a strong predictor of the mean probability of adequacy in multivariate models for both men and women (Table 5).

We chose a definition of dietary variety that parallels the one used for the HEI (18). It allowed us to calculate both total variety, and variety within each of the FGP food groups, after disaggregating mixed foods. The variety codes are broadly based on the type of agricultural commodity, and not on the form of the food, the method of preparation, or the amount of added fat, sugar, or sodium. This definition of variety counts

TABLE 3

Food Guide Pyramid servings and variety counts on the first 24-h recall day among CSFII adults[1,2]

	Men (n = 4969)	Women (n = 4800)
Dairy servings	1.5 ± 0.03	1.2 ± 0.02
Cheese	0.5 ± 0.02	0.4 ± 0.01
Milk	0.9 ± 0.02	0.7 ± 0.02
Yogurt	0.03 ± 0.00	0.04 ± 0.00
Dairy variety	0.9 ± 0.02	0.8 ± 0.02
Fruit servings	1.5 ± 0.04	1.5 ± 0.04
Citrus, melon, and berry	0.8 ± 0.03	0.8 ± 0.03
Other fruits	0.8 ± 0.02	0.7 ± 0.02
Fruit variety	0.9 ± 0.02	0.9 ± 0.02
Vegetable servings	3.8 ± 0.05	3.0 ± 0.03
Deep yellow vegetables	0.2 ± 0.01	0.2 ± 0.01
Dark green vegetable	0.2 ± 0.01	0.2 ± 0.01
White potatoes	1.3 ± 0.04	0.9 ± 0.03
Other starchy vegetables	0.3 ± 0.02	0.2 ± 0.01
Tomatoes	0.6 ± 0.01	0.4 ± 0.01
Other vegetable servings	1.3 ± 0.02	1.1 ± 0.02
Vegetable variety	2.1 ± 0.03	1.8 ± 0.02
Grain servings	7.7 ± 0.08	5.7 ± 0.05
Whole-grain	1.1 ± 0.05	0.9 ± 0.03
Non-whole-grain	6.6 ± 0.07	4.8 ± 0.04
Grain variety	2.1 ± 0.02	2.0 ± 0.02
Meat/protein servings	2.6 ± 0.03	1.6 ± 0.02
Legumes	0.1 ± 0.01	0.1 ± 0.00
Eggs	0.2 ± 0.01	0.1 ± 0.00
Fish and other seafood	0.2 ± 0.01	0.2 ± 0.01
Frankfurters and luncheon meats	0.4 ± 0.01	0.2 ± 0.01
Beef, pork, and lamb	1.0 ± 0.02	0.6 ± 0.01
Nuts and seeds	0.1 ± 0.00	0.04 ± 0.00
Organ meats	0.01 ± 0.00	0.01 ± 0.00
Poultry	0.6 ± 0.02	0.4 ± 0.02
Soy products	0.01 ± 0.00	0.01 ± 0.00
Meat/protein variety	2.1 ± 0.02	1.7 ± 0.02
Total variety	8.0 ± 0.06	7.3 ± 0.04

[1] All analyses were adjusted for sample weights and the clustered survey design.
[2] Values are means ± SEM.

only basic foods that fall within the major FGP food groups, and thus reflects intake of foods that can contribute to a healthy diet. Foods such as candy, soft drinks, table fats, salad dressings, and coffee/tea are not counted.

However, there are many other ways to define dietary variety, and other definitions may not be associated with nutrient adequacy. Furthermore, some of the misunderstandings about past dietary guidance to consume a variety of foods probably stem from the lack of a clear definition in the minds of consumers. Some consumers have indicated that they interpret dietary variety to mean the consumption of different flavors or forms of foods that would not be considered healthy, such as a variety of candy bars (5). Recent findings by McCrory et al. (4) demonstrated that consuming a variety of foods from food groups such as "sweets, snacks, and carbohydrates" was associated with increased body fat, whereas consumption of a variety of vegetables was associated with decreased body fat. Similarly, Bernstein et al. (22) found that a score of variety for all foods was associated with increased intakes of energy, fat, and cholesterol, whereas a fruit and vegetable variety score was not. Drewnowski et al. (23) used a dietary variety score based on 113 food codes, which were heavily weighted toward fruit and vegetable types. They found that dietary variety was positively associated with vitamin C intakes, and negatively associated with intakes of sugar, saturated fat, and sodium. Other researchers defined dietary variety, or dietary diversity, as a score of the number of food groups, as opposed to food items, consumed (3,24). This type of variety is sometimes called between-group variety. Completely eliminating one or more of the major food groups from a diet is almost always associated with poorer nutrient intakes, and thus higher scores for between-group variety tend to predict better nutrient adequacy and health outcomes. It appears that the definition of dietary variety can substantially affect whether consuming a variety of foods is desirable.

It is important to note that dietary variety, food group intakes, and nutrient adequacy are all strongly correlated with energy intake. Indeed, energy intake plus 4 nondietary variables (age, education, ethnicity, and BMI) explained 54–60% of the variance in the mean probability of nutrient adequacy. Adjusting for energy intake substantially reduced associations of both food group intakes and variety counts with nutrient adequacy (Table 4). Thus, it is crucial that the contribution of dietary variety to nutrient adequacy be evaluated in multivariate models adjusting for energy intake. The association of variety with energy consumption can be viewed as a reason not to recommend dietary variety, and it appears that reducing dietary variety can reduce energy intakes (25), and perhaps also the risk of obesity. Thus, any guidance to consumers that promotes dietary variety should emphasize that the goal is to alter variety within the context of a diet that maintains appropriate energy balance. Furthermore, the association of variety with energy intake is stronger for some food groups than for others, i.e., adjusting for energy intake had little effect on the correlations between fruit variety and nutrient adequacy, but this same adjustment essentially eliminated the

TABLE 4

Unadjusted and energy-adjusted correlations of primary Food Guide Pyramid servings and variety counts with mean probability of adequacy (index of 15 micronutrients) for 1-d intakes among CSFII adults[1,2]

	Correlation with mean probability of adequacy[3]			
	Men (n = 4969)		Women (n = 4800)	
	Unadjusted	Energy-adjusted	Unadjusted	Energy-adjusted
Energy	0.72	NA	0.69	NA
FGP groups				
Dairy	0.51	0.29	0.50	0.30
Fruit	0.34	0.25	0.37	0.27
Vegetables	0.40	0.17	0.37	0.19
Grains	0.49	0.06	0.47	0.07
Meat/protein	0.35	0.03	0.35	0.11
Within group variety counts				
Dairy variety	0.43	0.24	0.43	0.26
Fruit variety	0.31	0.26	0.33	0.26
Vegetable variety	0.39	0.20	0.36	0.21
Grain variety	0.41	0.26	0.40	0.23
Meat/protein variety	0.27	0.03	0.27	0.06
Total variety	0.68	0.44	0.68	0.46

[1] Correlations are Spearman's ρ.
[2] All analyses were adjusted for sample weights and the clustered survey design.
[3] All correlations are significant ($P < 0.05$) except the energy-adjusted correlation of the meat/protein servings with the mean probability of adequacy among men ($\rho = 0.03$).

TABLE 5

Linear regression models of factors contributing to the mean probability of adequacy for CSFII adults[1–3]

		Mean probability of adequacy			
		Men		Women	
Model	Factor(s)	Parameter estimate (SE)	Model R^2	Parameter estimate (SE)	Model R^2
1	Energy	40.62 (0.71)	0.60	44.97 (0.67)	0.54
2	FGP groups		0.69		0.66
	Dairy	3.62 (0.20)		6.28 (0.24)	
	Fruit	1.66 (0.15)		2.03 (0.26)	
	Vegetables	1.28 (0.08)		2.03 (0.14)	
	Grains	0.44 (0.07)		1.03 (0.11)	
	Meat/proteins	0.72 (0.08)		2.03 (0.16)	
3	FGP groups and total variety		0.73		0.70
	Dairy	2.77 (0.17)		5.10 (0.21)	
	Fruit	0.71 (0.11)		0.96 (0.14)	
	Vegetables	0.52 (0.08)		0.87 (0.13)	
	Grains	0.23 (0.07)		0.70 (0.11)	
	Meat/proteins	0.48 (0.07)		1.51 (0.14)	
	Total variety	2.21 (0.10)		2.77 (0.13)	
4	FGP groups and variety within FGP groups		0.73		0.71
	Dairy	2.26 (0.17)		4.21 (0.28)	
	Fruit	0.52 (0.15)		0.99 (0.24)	
	Vegetables	0.83 (0.11)		1.34 (0.17)	
	Grains[3]	0.09 (0.07)		0.48 (0.11)	
	Meat/proteins	0.66 (0.09)		1.74 (0.16)	
	Dairy variety	3.32 (0.42)		4.48 (0.41)	
	Fruit variety	2.46 (0.27)		2.62 (0.44)	
	Vegetable variety	1.32 (0.17)		1.68 (0.29)	
	Grain variety	3.74 (0.23)		4.38 (0.30)	
	Meat/protein variety	1.15 (0.20)		1.87 (0.29)	

[1] All analyses were adjusted for sample weights and the clustered survey design; all models include energy and are adjusted for age, education level, BMI, and ethnicity.

[2] The model with only the 4 nondietary variables explained little of the variability in the mean probability of adequacy ($R^2 = 0.04$).

[3] All parameter estimates and model R^2 values were significant ($P < 0.005$) with the exception of grain servings in model #4 for men (P-value for grain servings = 0.20).

association between meat/protein variety and nutrient adequacy (Table 4).

The present analyses examined only a single day of intake data. Although 1 d of intake is not representative of usual intake due to day-to-day variations (26), it was adequate for our stated purpose, i.e., to examine associations among dietary variety, energy intake, food group intake, and the probability of nutrient adequacy. Preliminary examinations indicated that the findings would not have changed with the inclusion of d 2 of intake data, and thus it is likely that the associations seen for 1 d are similar to those that would be observed over a longer period of time.

Adding dietary variety to models of nutrient adequacy increased the explanatory power by only 4% over models with energy intake and servings of FGP food groups as the predictor variables (Table 5). However, an examination of the coefficients in these models shows that total variety was a better predictor of nutrient adequacy than any of the food group serving measures except the number of servings of dairy products. When total variety was separated into within-group measures of variety, dairy variety and grain variety were stronger predictors of nutrient adequacy than any of the food group serving variables. For adults in the U.S., some of the most at-risk nutrients in the diet are those supplied by dairy products (calcium and vitamin A) and grains (folate and magnesium). Adults who chose an additional serving of a different type of these foods obtained a higher level of at-risk nutrients than adults who chose an additional serving of the same type of dairy products and grain products on the recall day. The number of servings of grains was relatively unimportant in all of the models. Consuming a variety of fruits and vegetables also was more important than the number of servings from these food groups.

Variety was not high for these 1-d diets. On average, the participants in the CSFII reported only 7–8 different commodities in a day. Only food intakes that summed to at least a half-serving over the day were included in our variety count, which may partially explain the low variety. However, when we relaxed this requirement to one-quarter serving per day, there was very little change, i.e., the dietary variety count, on average, increased by ~1.5 foods. Future dietary guidance may have to focus on helping consumers identify a desirable level of variety in a day, or over several days. For example, women who consumed an additional serving of dairy products per day increased their nutrient adequacy score by ~4%, and those that also consumed an additional type of dairy products increased their score by another 4.5%. Thus, adding a serving of a different dairy product to the 1.2 dairy servings in the current diet could increase women's mean nutrient adequacy score by 8.5%, or from 57.7 to 66.2%. However, the variables for variety and for servings are highly correlated, and thus it is difficult to separate the effects with certainty. In spite of this confounding, it is reasonable to assume that persons who choose 2 servings of the same food obtained fewer at-risk nutrients than persons with the same 2 servings, but from 2 or more types of foods.

This is one of the first studies to examine the effect of dietary variety on nutrient adequacy using the new DRIs. The findings reported here show that consuming different commodities in a day contributed significantly to the mean probability of nutrient adequacy among CSFII adults, even after adjusting for energy intake and for the number of servings of the FGP food groups. Thus, the results support dietary guidance that recommends choosing a variety of basic food commodities within each of the FGP food groups.

ACKNOWLEDGMENTS

The authors acknowledge the contributions of Kim Murakami for revisions to the variety coding database and Kami White for assistance with statistical analyses.

LITERATURE CITED

1. Welsh, S. O., Davis, C. & Shaw, A. (1993) USDA's Food Guide, Background and Development. Human Nutrition Information Service Miscellaneous Publication, Report #1514. United States Department of Agriculture, Hyattsville, MD.

2. U.S. Department of Agriculture, Dietary Guidelines Advisory Committee 2000 (2000) Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans (2000) to the Secretary of Agriculture and the Secretary of Health and Human Services. United States Department of Agriculture, Washington, DC.

3. Krebs-Smith, S. M., Smiciklas-Wright, H., Guthrie, H. A. & Krebs-Smith, J. (1987) The effects of variety in food choices on dietary quality. J. Am. Diet. Assoc. 87: 897–903.

4. McCrory, M. A., Fuss, P. J., McCallum, J. E., Yao, M., Vinken, A. G., Hays, N. P. & Roberts, S. B. (1999) Dietary variety within food groups: association with energy intake and body fatness in men and women. Am. J. Clin. Nutr. 69: 440–447.

5. Prospect Associates (1998) Dietary Guidelines for American Focus Group Study Final Report. Prospect Associates (now part of American Institutes for Research), Silver Spring, MD.

6. Kant, A. K. (1996) Indexes of overall diet quality: a review. J. Am. Diet. Assoc. 96: 785–791.

7. Bowman, S. A., Lino, M., Gerrior, S. A. & Basiotis, P. P. (1998) The Healthy Eating Index: 1994–96. USDA Center for Nutrition Policy and Promotion, CNPP-5. Washington, DC.

8. Tippett, K. S. & Cypel, Y. S., eds. (1998) Design and Operation: The Continuing Survey of Food Intakes by Individuals and Diet and Health Knowledge Survey, 1994–1996, NFS Report no. 96–1. U.S. Department of Agriculture, Agricultural Research Service, Riverdale, MD.

9. U.S. Department of Agriculture, Agricultural Research Service (1998) Continuing Survey of Food Intakes for Individuals, 1994–1996. National Technical Information Service Accession No. PB98–500457. U.S. Department of Agriculture, Beltsville Human Nutrition Research Center, Beltsville, MD.

10. U.S. Department of Agriculture, Center for Nutrition Policy and Promotion (1996) The Food Guide Pyramid. Home and Garden Bulletin no. 252. U.S. Government Printing Office, Washington, DC.

11. Institute of Medicine Food and Nutrition Board (1997) Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride. National Academy Press, Washington, DC.

12. Institute of Medicine Food and Nutrition Board (1998) Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. National Academy Press, Washington, DC.

13. Institute of Medicine Food and Nutrition Board (2000) Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. National Academy Press, Washington, DC.

14. Institute of Medicine Food and Nutrition Board (2000) Dietary Reference Intakes. Applications in Dietary Assessment. National Academy Press, Washington, DC.

15. Institute of Medicine Food and Nutrition Board (2001) Dietary Reference Intakes for Vitamin a, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. National Academy Press, Washington, DC.

16. SAS Institute Inc. (1999) SAS. The SAS Institute, Cary, NC.

17. Basiotis, P. P., Carlson, A, Gerrior, S. A., Juan, W. Y. & Lino, M. (2002) The Healthy Eating Index: 1999–2000. CNPP-12. U.S. Department of Agriculture, Center for Nutrition Policy and Promotion, Washington, DC.

18. Kennedy, E., Ohls, J., Carlson, S. & Fleming, K. (1994) The Healthy Eating Index Final Report. Mathematica Policy Research, Princeton, NJ.

19. Research Triangle Institute (2002) SUDAAN. Survey Data Analysis Software. Research Triangle Park, NC.

20. McCulloch, C. E. & Searle, S. R. (2001) Generalized, Linear, and Mixed Models. John Wiley and Sons, New York, NY.

21. Guthrie, H. A. & Scheer, J. C. (1981) Validity of a dietary score for assessing nutrient adequacy. J. Am. Diet. Assoc. 78: 240–245.

22. Bernstein, M. A., Tucker, K. L., Ryan, N. D., O'Neill, E. F., Clements, K. M., Nelson, M. E., Evans, W. J. & Fiatarone Singh, M. A. (2002) Higher dietary variety is associated with better nutritional status in frail elderly people. J. Am. Diet. Assoc. 102: 1096–1104.

23. Drewnowski, A., Henderson, S. A., Driscoll, A. & Rolls, B. J. (1997) The Dietary Variety Score: assessing diet quality in healthy young and older adults. J. Am. Diet. Assoc. 97: 266–271.

24. Kant, A. K., Schatzkin, A., Harris, T. B., Ziegler, R. G. & Block, G. (1993) Dietary diversity and subsequent mortality in the First National Health and Nutrition Examination Survey Epidemiologic Follow-Up Study. Am. J. Clin. Nutr. 57: 434–440.

25. Rolls, B. J. & Hetherington, M. (1989) The role of variety in eating and body weight regulation. In: Handbook of Psychophysiology of Human Eating (Shepherd, R., ed.), pp. 57–84. John Wiley and Sons, New York, NY.

26. Basiotis, P. P., Welsh, S. O., Cronin, F. J., Kelsay, J. L. & Mertz, W. (1987) Number of days of food intake records required to estimate individual and group nutrient intakes with defined confidence. J. Nutr. 117: 1638–1641.