The American Journal of Clinical Nutrition

Downloaded from ajcn.nutrition.org by guest on May 29, 2016

Dietary variety within food groups: association with energy intake and body fatness in men and women[1–3]

Megan A McCrory, Paul J Fuss, Joy E McCallum, Manjiang Yao, Angela G Vinken, Nicholas P Hays, and Susan B Roberts

See corresponding editorial on page 350.

ABSTRACT

Background: Short-term experimental studies suggest that dietary variety may influence body fatness but no long-term human studies have been reported.

Objective: The purpose of this study was to determine whether dietary variety within food groups influences energy intake and body fatness.

Design: Seventy-one healthy men and women (aged 20–80 y), who provided accurate reports of dietary intake and completed a body-composition assessment, were studied.

Results: Dietary variety was positively associated with energy intake within each of 10 food groups (r = 0.27–0.56, $P < 0.05$). In multiple regression analysis with age and sex controlled for, dietary variety of sweets, snacks, condiments, entrées, and carbohydrates (as a group) was positively associated with body fatness (partial r = 0.38, P = 0.001) whereas variety from vegetables was negatively associated (partial $r = -0.31$, P = 0.01) (R^2 = 0.46, $P < 0.0001$). In separate models, both a variety ratio (variety of vegetables/variety of sweets, snacks, condiments, entrées, and carbohydrates) and percentage dietary fat were significant predictors of body fatness (controlled for age and sex, partial $r = -0.39$ and 0.31, respectively, $P < 0.01$). However, dietary fat was no longer significantly associated with body fatness when the variety ratio and dietary fat were included in the same model.

Conclusions: Our data, coupled with those of previous short-term studies, suggest that a high variety of sweets, snacks, condiments, entrées, and carbohydrates coupled with a low variety of vegetables promotes long-term increases in energy intake and body fatness. These findings may help explain the rising prevalence of obesity. *Am J Clin Nutr* 1999;69:440–7.

KEY WORDS Dietary variety, dietary fat, dietary composition, body composition, obesity, energy intake, adults, vegetables

INTRODUCTION

The prevalence of obesity is increasing worldwide (1) and >50% of the adult population in the United States is now considered to be overweight or obese (2). Although diet, physical activity, and genetic factors undoubtedly all contribute to the development of obesity, the specific underlying causes of adult weight gain remain elusive (3).

Of the many dietary factors that have been implicated, the percentage of energy from dietary fat has received particular attention (4, 5). Recently, however, an expert panel concluded that dietary fat may not be the sole dietary determinant of body fatness it has widely been assumed to be (6). Additional research is therefore needed to examine other dietary contributors to weight gain and obesity.

One potential factor that has received relatively little attention in humans is dietary variety. In laboratory animals, access to a variety of foods increases energy intake within and between meals compared with access to a single food (7–14) and over the long term induces weight gain and fat gain (9, 11). Results of single-meal studies in humans are consistent with animal data, showing that subjects consume more total food when offered a variety of different foods than when only a single food is presented (15–20). However, it is not known whether the effects of dietary variety on food intake in humans persist in the long term and lead to changes in body weight and fat content. If so, and in view of the fact that the variety of commercial foods has risen dramatically in recent years (21), excessive dietary variety might help to explain the rising national prevalence of obesity.

The purpose of this study was to test the hypothesis that dietary variety is associated with energy intake and body fatness in free-living adults consuming self-selected diets. In addition, we hypothesized that the relation between dietary variety and body fatness depends critically on the types of foods being consumed. Specifically, high variety is associated with fatness when the variety comes from foods with a high energy content, but with leanness when the variety comes from foods with a low energy content. In addition, we also tested dietary variety as a predictor of body fatness relative to other putative dietary predictors

[1] From the Energy Metabolism Laboratory, The Jean Mayer US Department of Agriculture Human Nutrition Research Center on Aging at Tufts University, Boston.

[2] Supported in part by grants AG00209, AG12829, DK09747, DK46124, and DK46200 from the National Institutes of Health.

[3] Address reprint requests to SB Roberts, Energy Metabolism Laboratory, The Jean Mayer US Department of Agriculture Human Nutrition Research Center on Aging at Tufts University, 711 Washington Street, Boston, MA 02111–1524. E-mail: Roberts_em@hnrc.tufts.edu.

Received July 14, 1998.

Accepted for publication November 12, 1998.

of body fatness, including the proportion of dietary energy derived from fat, energy density, fiber, and energy intake per kilogram body weight.

SUBJECTS AND METHODS

Subjects

Subjects were 71 adult men and women who had participated in studies on diet and body composition at The Jean Mayer US Department of Agriculture Human Nutrition Research Center on Aging at Tufts University and who provided complete and accurate records of dietary intake [energy intake within 30% of predicted energy requirements (22)]. The ±30% range was chosen to exclude subjects whose reported energy intake was physiologically implausible, given that subjects needed to be weight stable to participate. In addition to being weight stable, all subjects were free of disease, not taking any medications that influence energy regulation, and judged healthy according to results of a physical examination, an electrocardiogram, and routine blood and urine tests. The protocols were approved by the Human Investigation Review Committee at New England Medical Center and Tufts University and all subjects gave written, informed consent before participating.

Dietary intake

Usual dietary intake over the preceding 6 mo was assessed by using the Fred Hutchinson Cancer Research Center Food Frequency Questionnaire (FFQ), version 06.10.88 (modified Block; 23); energy and macronutrient intakes were calculated by using Minnesota NDS software (food database version 11A, nutrient database version 2.8; Nutrition Coordination Center, University of Minnesota, Minneapolis). Energy density was calculated as the total daily energy consumption divided by the total daily weight of food consumed, including all beverages.

Dietary variety within food groups was assessed in the following manner. First, 10 food groups were formed by using the FFQ food groupings as an initial basis on which to combine food types listed, and slight modifications were made according to each food type's place in the diet and physical state (beverages and solid foods). For example, breakfast food condiments were separated from the remaining breakfast foods. The 10 food groups and the number of food types within each group are shown in **Table 1** along with representative food types in each group; a complete list is given in **Appendix A**. These 10 initial food groups were later collapsed into 8 groups on the basis of the results of multiple regression analyses (*see* Data analysis). Because of the nature of standard FFQs, some individual foods were already grouped together and thus could not be distinguished from one another. For example, "apples, applesauce, and pears" is the first item listed on the FFQ and, for the purpose of this analysis, all 3 items were considered 1 food type.

Dietary variety was then calculated as the percentage of different food types consumed within each food group, regardless of the frequency with which they were consumed. In addition, the total daily energy intake from each food group was determined by multiplying each food type's frequency of consumption by the portion size usually consumed (small, medium, or large) and the energy content of the food type according the Minnesota Nutrient Database.

Body composition

Body weight and height were measured to the nearest 0.01 kg and 0.25 cm, respectively, and body composition was measured by hydrostatic weighing after subjects fasted overnight (24). Body density was corrected for residual lung volume measured on land by the nitrogen washout method (model 505, Med Science Nitralyzer, St Louis; Sensormedics Vmax, Yorba Linda, CA) (25). Fat mass and fat-free mass were calculated by using the equation of Siri (26), and the average of 4 tests with results within 1% body fat was used for analysis.

Data analysis

Statistical analyses were performed by using SYSTAT software (version 7.0.1; SPSS, Inc, Chicago). Descriptive data are presented as means ± SDs unless otherwise indicated. To determine whether dietary variety was associated with the amount of food consumed within a food group, Pearson correlation coefficients between dietary variety and the energy intake per day from each food group were calculated. Pearson correlations were also calculated to determine associations among the different dietary variables. Stepwise multiple linear regression analysis was used to determine the association between dietary variety and body fatness (expressed as % of wt). All 10 initial food groups, as well as several combinations of food groups, were tested. On the basis of trends noted in regression analysis, certain food groups were combined to create food group combina-

TABLE 1
Food group descriptions

Food group	Number of food types	Representative food types
Breakfast foods	7	Cold cereals, cooked cereals, eggs, bacon, and sausage
Lunch and dinner entrées[1]	19	Beef, pork, chicken, tuna, fried fish, hamburgers, pot pie, stew, spaghetti, pizza, luncheon meats, and chili
Sweets, snacks, and carbohydrates[1]	18	Ice cream, sherbet, frozen yogurt, pies, candy, jelly, honey, French fries, potato chips, popcorn, muffins, cakes, doughnuts, cookies, potatoes, rice, and bread
Condiments[1]	7	Butter, margarine, salad dressing, mayonnaise, gravy, and peanut butter
Fruit	10	Apples, bananas, peaches, citrus fruit, berries, and watermelon
Vegetables	14	Broccoli, carrots, spinach, green salad, corn, beans, and peas
Energy-containing beverages	9	Orange and grapefruit juices, milk, regular soft drinks, beer, and wine
Dairy products	5	Yogurt, cottage cheese, and other cheeses
Breakfast food condiments	2	Milk added to cereal and sugar added to cereal
Beverage condiments	4	Milk, cream, half-and-half, nondairy creamer, and sugar

[1]These 3 groups were later combined into 1 food group on the basis of results of multiple regression analyses (*see* Data analysis section for details).

Downloaded from ajcn.nutrition.org by guest on May 29, 2016

tions. For example, when variety in more than one food group was positively associated with body fatness, the food groups were combined and the variety score was recomputed from the new, larger food group and regression analysis was repeated. Variety was recomputed as the number of food types consumed from the new food group divided by all possible food types in the new, larger group (eg, there were 44 possible food types for the combined sweets, snacks, condiments, entrées, and carbohydrates group; *see* Table 1 and Appendix A for the number of possible food types in each of the original 10 food groups) and converted to a percentage. Data are presented for the resulting individual and combinations of food groups that yielded the highest R^2 values in regression analyses. To compare the relative predictive value of dietary variety within food groups on body fatness with other putative dietary predictors of body fatness, partial correlations of each dietary variable with body fatness were computed (after age and sex were controlled for). For all statistical tests, a P value <0.05 was accepted as significant.

RESULTS

As shown in **Table 2**, the subjects varied widely in age and fatness. Their dietary intakes also varied widely, but were not unusual. Information on the dietary variety consumed within each food group in the preceding 6 mo (expressed as a percentage of total possible group variety) is shown in **Table 3**. The mean dietary variety ranged between 32% and 80% for the 10 different food groups. In all food groups, there was substantial variability among subjects, with some individuals consuming little variety and others consuming a much greater variety. For example, women consumed between 7% and 100% of the possible vegetable types. Pearson correlations of age with the different dietary variables indicated that older subjects consumed a greater variety of vegetables (r = 0.51, P < 0.001) and, hence, had a greater intake of fiber per megajoule energy consumed (r = 0.32, P < 0.05) and a lower energy intake per kilogram body weight (r = −0.49, P < 0.001) than did younger subjects.

The relation between dietary variety and energy intake per day in 8 of the 10 food groups is shown in **Figure 1**. In all 8 food groups, there was a significant positive association between dietary variety and energy intake derived from each specific food group (r = 0.27–0.52, P < 0.05). Results were similar for the remaining 2 groups, breakfast food condiments (r = 0.29, P = 0.01) and beverage condiments (r = 0.56, P < 0.0001) (data not shown). Thus, within every food group tested, consumption of a greater variety of foods was associated with a greater energy intake from those foods.

The question of whether dietary variety could predict body fatness was examined by using multiple regression analysis, controlling first for the effects of age and sex on body fatness. Initially, all 10 food groups were tested separately. Of these 10 groups, in separate models, variety from each of 4 food groups was positively associated with body fatness after age and sex were controlled for (breakfast foods, partial R = 0.27, P = 0.03; lunch and dinner entrées, partial R = 0.28, P = 0.02; sweets, snacks, and carbohydrates, partial R = 0.22, P = 0.07; and condiments, partial R = 0.28, P = 0.02), and variety from 1 group was negatively associated (vegetables, partial R = −0.21, P = 0.09). Because the partial correlations of the food groups positively related to body fatness were similar, several combinations of these food groups were tested in subsequent analyses. Results of the analysis that produced the highest R^2 value are shown in **Figure 2**. After age and sex were controlled for, in a single model, variety from the vegetables group was negatively associated with body fatness, and variety from the combined group of sweets, snacks, condiments, entrées, and carbohydrates was positively associated with body fatness. Interaction terms of dietary variety with age were not significant, indicating that age did not modify the relation between dietary variety and body fatness in this study population. The overall best-fit regression model, controlled for age and sex and containing dietary variety from these 2 food groups, yielded an R^2 of 0.46 (P < 0.0001). Models in which the entrées group and different combinations of sweets, snacks, carbohydrate, and condiments groups were considered separately, and were also significant, but yielded lower R^2 values. Dietary variety scores in the remaining food groups were not significant predictors of body fatness.

In addition to the 2 variety variables that were significantly related to body fatness in the multiple regression analysis

TABLE 2
Characteristics and dietary intake of the subjects[1]

	Women (n = 58)	Men (n = 13)
Characteristics		
Age (y)	52 ± 15 (20–80)	55 ± 15 (30–73)
Weight (kg)	64.6 ± 11.3 (48.8–100.3)	82.4 ± 10.5 (72.2–102.0)
Height (cm)	163.4 ± 7.3 (150.5–179.3)	179.8 ± 4.1 (173.3–185.9)
BMI (kg/m^2)	24.2 ± 4.0 (18.6–38.5)	25.5 ± 3.3 (21.9–32.6)
Body fat (% of wt)	33.9 ± 9.8 (10.3–57.7)	21.2 ± 7.1 (11.4–33.0)
Dietary intake		
Energy intake (MJ/d)	8.7 ± 2.0 (5.6–14.2)	11.3 ± 2.5 (8.3–16.0)
(MJ·d^{-1}·kg body wt^{-1})	0.14 ± 0.03 (0.09–0.22)	0.14 ± 0.03 (0.10–0.19)
Energy density (kJ/g)	3.74 ± 0.92 (2.19–6.32)	3.65 ± 1.11 (1.35–5.76)
Carbohydrate (% of energy)	48.5 ± 8.6 (29.5–65.0)	45.4 ± 9.6 (32.3–69.2)
Protein (% of energy)	16.4 ± 2.6 (10.4–22.7)	15.5 ± 3.6 (10.3–21.4)
Alcohol (% of energy)	2.3 ± 3.8 (0–19.1)	6.8 ± 7.8 (0–20.2)
Total fat (% of energy)	34.7 ± 7.3 (20.4–54.5)	33.9 ± 8.2 (19.9–46.2)
Saturated fat (% of energy)	13.1 ± 3.2 (6.5–20.2)	12.5 ± 3.4 (7.1–18.4)
Fiber (g/MJ)	2.2 ± 0.8 (0.7–4.4)	1.9 ± 0.6 (0.9–3.2)

[1] $\bar{x}$ ± SD; range in parentheses.

The American Journal of Clinical Nutrition

Downloaded from ajcn.nutrition.org by guest on May 29, 2016

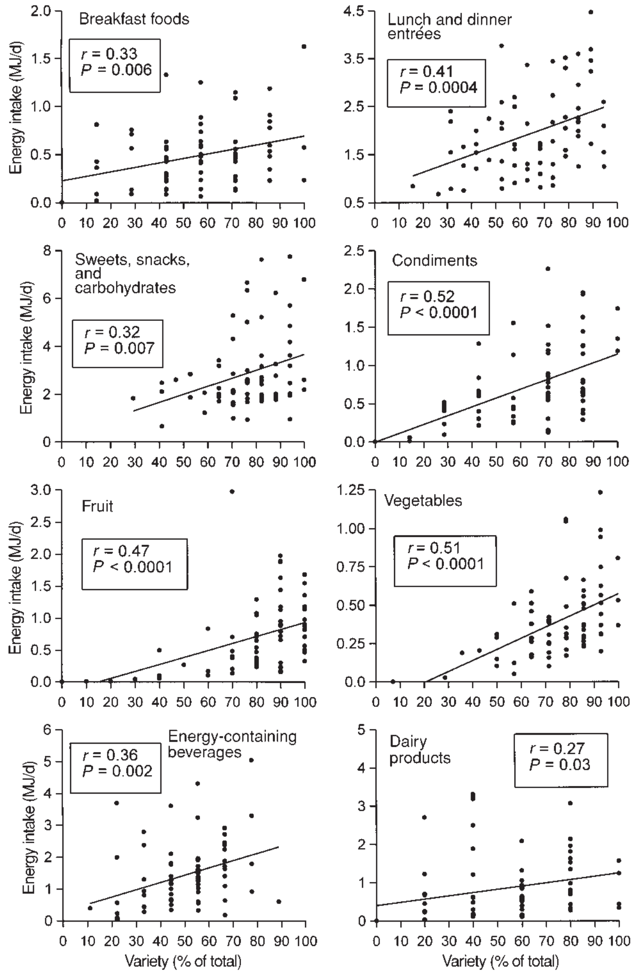

FIGURE 1. Energy intake per day from 8 food groups in relation to dietary variety within each group. Values are individual data points for the 71 subjects. Associations were similar for the 2 food groups not shown. Note that the *y* axis values differ for each graph.

described above, the ratio between these 2 variables was calculated to create a composite variety variable. This composite dietary variety variable, termed the "variety ratio," was calculated as the ratio of the variety of vegetables consumed (75.3 ± 17.5%) to the variety of sweets, snacks, condiments, entrées, and carbohydrates consumed (69.3 ± 15.3%). The mean variety ratio was 1.13 ± 0.35. Pearson correlations between these 3 variety variables and other dietary variables are shown in **Table 4**. As shown, variety from the vegetables group was negatively associated with energy intake per kilogram body weight, and positively associated with dietary fiber intake (per MJ consumed). Variety from the sweets, snacks, condiments, entrées, and carbohydrates group was positively associated with dietary fat intake and energy density and negatively associated with fiber intake. The variety ratio was negatively associated with dietary fat intake and energy density and positively associated with fiber intake.

To compare the relative strength of the variety ratio in predicting body fatness with other putative predictors of body fatness, including percentage of dietary fat, energy density, fiber, and energy intake per kilogram body weight, partial correlations of these variables with body fatness (controlling for age and sex) were computed. Of these, only the variety ratio (partial $R = -0.39$, $P = 0.001$) and dietary fat (partial $R = 0.31$, $P = 0.009$) were significant predictors of body fatness. Because the variety ratio was positively associated with dietary fat (Table 4), the ratio was tested for its association with body fatness after dietary fat was controlled for. As can be seen in **Figure 3**, the variety ratio remained significantly associated with body fatness, even after dietary fat was controlled for ($R^2 = 0.44$, $P < 0.0001$). Furthermore, dietary fat was no longer significantly related to body fatness once both dietary variety and dietary fat were included in the same regression model.

DISCUSSION

The results of this study suggest that dietary variety, and the types of foods that provide it, may be an important determinant of body fatness in adult men and women. In addition, our results imply that changes in dietary variety patterns are a likely contributor to the rising prevalence of obesity nationally and worldwide.

In multiple regression models accounting for age and sex, we observed for the first time a significant association between body fatness and dietary variety within different food groups. Most noteworthy, the relation between dietary variety and body fatness was shown to depend on the food group that provided it. For sweets, snacks, condiments, entrées, and carbohydrates there was a positive association between body fatness and variety. In contrast, there was a negative association between body fatness and the variety of vegetables (excluding potatoes) consumed. Moreover, the variety ratio was the strongest predictor of body fatness, and the proportion of dietary energy provided by fat was not a significant predictor of body fatness in regression models that included the variety ratio. Thus, dietary variety was found to be a double-edged sword for energy regulation, having both positive and negative associations with body fatness depending on the food group that provided the variety.

Note that our study probably underestimated the effects of dietary variety on body fatness. This is because we used an FFQ to obtain dietary data and this kind of instrument limits the information that can be obtained on variety within different food groups. Thus, it is possible that even stronger relations between dietary variety and body fatness may be found with use of food

TABLE 3
Dietary variety[1]

	Women	Men
	%	
Breakfast foods	56 ± 23 (0–100)	57 ± 25 (14–100)
Lunch and dinner entrées	66 ± 20 (16–95)	64 ± 19 (37–95)
Sweets, snacks, and carbohydrates	78 ± 15 (29–100)	70 ± 15 (41–94)
Condiments	63 ± 22 (0–100)	66 ± 28 (14–100)
Fruit	80 ± 23 (0–100)	68 ± 29 (0–100)
Vegetables	75 ± 18 (7–100)	75 ± 15 (50–100)
Energy-containing beverages	54 ± 22 (0–100)	60 ± 20 (17–83)
Dairy products	46 ± 19 (13–88)	45 ± 22 (13–88)
Breakfast food condiments	58 ± 34 (0–100)	77 ± 26 (50–100)
Beverage condiments	32 ± 29 (0–75)	35 ± 38 (0–100)

[1] $\bar{x}$ ± SD; range in parentheses. Percentage of different food types per group consumed in the previous 6 mo as assessed by food-frequency questionnaire, regardless of the frequency of consumption.

The American Journal of Clinical Nutrition

Downloaded from ajcn.nutrition.org by guest on May 29, 2016

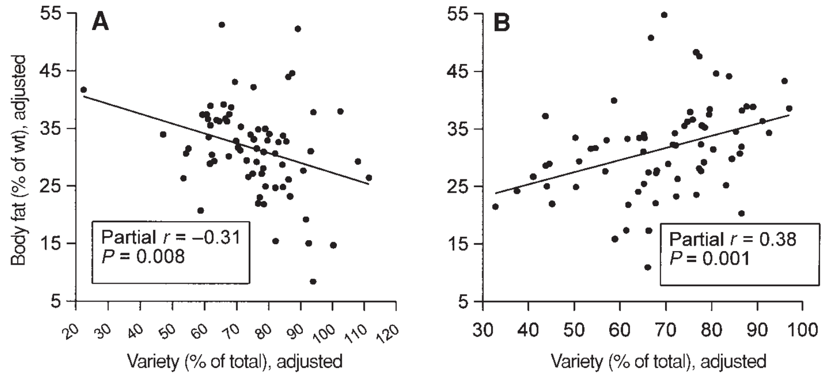

FIGURE 2. The associations between body fatness and dietary variety obtained from vegetables (A) and sweets, snacks, condiments, entrées, and carbohydrates (B). Partial correlations are shown, meaning that each relation is adjusted for age, sex, and dietary variety in the other food group. With the effects of age and sex controlled for in multiple regression analysis on percentage body fat, the variety of vegetables consumed was inversely associated with body fatness, and the variety of sweets, snacks, condiments, entrées, and carbohydrates consumed was positively associated with body fatness (overall $R^2 = 0.46$, $P < 0.0001$).

measurement methods, such as 7-d weighed intake, which allow specific information on each consumed item to be obtained.

Our additional finding that variety was positively associated with dietary intake within all food groups studied extends and is entirely consistent with results of previous single-meal studies in adults, a 4-d study in infants, and as short- and long-term studies in animal models (7–20, 27). Although the possibility cannot be ruled out that body fatness might influence dietary variety, the combination of our current cross-sectional data with previous single-meal studies in humans (15–20) and longer-term studies in rats (9, 11) strongly suggests that dietary variety exerts a long-term effect on body fatness through short-term influences on food and energy intake.

The fact that high variety was associated with increased energy intakes within the food groups tested in this study undoubtedly helps to explain the opposing associations of different food groups with body fatness. A notable difference between the foods that were positively associated with increased body fat (sweets, snacks, condiments, entrées, and carbohydrates) and the food group negatively associated with body fat (vegetables) is their energy density. Because adults tend to consume a constant daily weight of food (28, 29), increased amounts of low-energy vegetables, prompted by high variety, may replace rather than supplement intakes of higher-energy items and lead to an overall decrease in energy intake and hence body fatness. Conversely, increased amounts of high-energy sweets, snacks, and condiments, prompted by high variety, may increase energy intake and body fatness. Variety within groups defined as dairy products, energy-containing beverages, and fruit was not associated with body fatness in this study, perhaps because these staple foods tend to be eaten more out of habit than for interest, but also possibly because of the intermediate energy density of several of the food items within these groups.

A generalized and instinctive basis for the effects of dietary variety in humans is suggested by the fact that greater dietary variety is associated with greater food intake in all food groups and all species investigated to date. Although the mechanism by which a drive for dietary variety gets translated into increased food consumption is not known, the phenomenon of sensory-

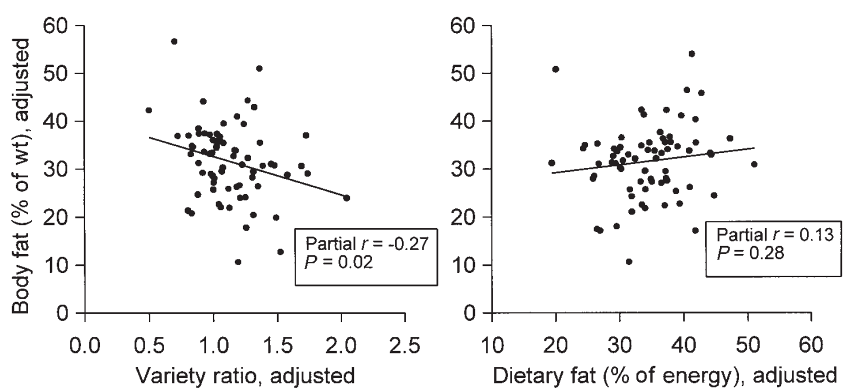

FIGURE 3. Associations between body fatness and the variety ratio, calculated as the ratio of the variety of vegetables to the variety of sweets, snacks, condiments, entrées, and carbohydrates (adjusted for age, sex, and percentage dietary fat), and percentage dietary fat (adjusted for age, sex, and the variety ratio). When the variety ratio and dietary fat were included in the same regression model, dietary fat was not significantly associated with body fatness ($R^2 = 0.44$, $P < 0.0001$).

The American Journal of Clinical Nutrition

Downloaded from ajcn.nutrition.org by guest on May 29, 2016

TABLE 4
Pearson correlations among dietary variables

	Variety of vegetables (%)	Variety of sweets, snacks, condiments, entrées, and carbohydrates (%)	Variety ratio (%)[1]
Energy intake ($MJ \cdot d^{-1} \cdot kg$ body wt^{-1})	−0.28[2]	−0.08	−0.11
Fat (% of energy)	−0.04	0.60[3]	−0.52[3]
Energy density (kJ/g)	−0.08	0.39[3]	−0.33[4]
Fiber (g/MJ)	0.43[3]	−0.25[2]	0.58[3]

[1]Calculated as the ratio of variety consumed from the vegetables group to that consumed from the sweets, snacks, condiments, entrées, and carbohydrates group.
[2]$P \leq 0.05$.
[3]$P \leq 0.001$.
[4]$P \leq 0.01$.

specific satiety (the term used to describe the fact that perception of food preference decreases as increasing amounts of that food are eaten) is a probable candidate (18, 19). In human prehistory, individuals who experienced sensory-specific satiety and ate from a greater variety of foods may well have had a better micronutrient status than individuals who ate a lesser variety of foods because no single basic food supplies every essential nutrient. Obtaining a balanced diet is harder when dietary choices are limited than when there is great dietary variety. Moreover, because the foods available to primitive hunters and foragers were both limited and intermittently available, those individuals who ate more total food when an increased variety of foodstuffs could be found may have fared better than those who did not. Thus, under the conditions existing when early humans evolved, individuals with a strong drive to eat a variety of foods and to increase total food intake in the presence of dietary variety were likely to have benefited from the metabolic, physical, and cognitive advantages that a balanced diet provides (30–33). What can be termed the "variety principle" may thus have been strongly beneficial in human prehistory, becoming favored in genetic selection and predominating in the lineage from which modern humans descend. Today, however, a drive to overeat when variety is plentiful is disadvantageous for weight regulation because dietary variety is greater than ever before and comes primarily from energy-dense commercial foods rather than from the energy-poor but micronutrient-rich vegetables and fruit for which the variety principle originally evolved.

There are several important implications for the observed influences of dietary variety on body fatness. In particular, dietary variety may be an important tool in the prevention and treatment of disorders of weight regulation. In situations in which an increase in energy intake is mandated, such as in elderly adults experiencing unexplained weight loss, increasing the variety of high-energy foods offered may accomplish the desired result without the necessity of intensive medical interventions.

Diets providing a high variety of vegetables and a low variety of sweets, snacks, condiments, entrées, and carbohydrates may promote a long-term reduction in voluntary energy intake and body fatness without resort to a conscious restriction of energy intake, thus preventing and perhaps helping to treat obesity and overweight. Our results may also help explain the rising national prevalence of obesity. The variety of vegetables now consumed is low (one-half of the total vegetable consumption in the United States is as fresh and frozen potatoes, head lettuce, processed tomatoes, and onions) and our data suggest that this may be a factor in limiting the total consumption to only 3.2 servings/d, on average (34). Moreover, an enormous number of high-energy commercial sweets, snacks, condiments, and carbohydrates have been introduced into the US food market in the past 30 y (21), which our model predicts will increase energy intake. As shown in **Figure 4**, these trends closely parallel the increasing national prevalence of obesity (2), and are strikingly out of proportion to the modest number of vegetable and fruit products introduced during the same period.

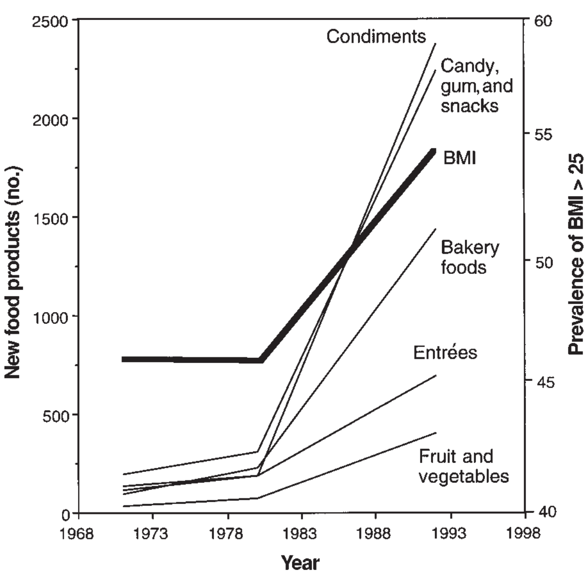

FIGURE 4. The number of food products introduced into the US food market classified as condiments, candy, snacks, and bakery foods parallels the increasing prevalence of obesity, and has increased strikingly out of proportion to new vegetable and fruit products. BMI in kg/m^2. (Data are from reference 2 for obesity and from reference 21 for food products).

In conclusion, the results of this study suggest that dietary variety, and the specific food groups that provide it, may be an important determinant of body fatness. Additional work is needed to investigate the importance of dietary variety relative to other putative determinants of weight regulation, such as physical activity and other dietary variables, and to examine in detail the role of dietary variety in the national and worldwide increases in the prevalence of obesity.

The American Journal of Clinical Nutrition

Downloaded from ajcn.nutrition.org by guest on May 29, 2016

We are grateful to Ana Sawaya, Gaston Bathalon, Chris Mosunic, and the Human Nutrition Research Center's Dietary Assessment Group for invaluable assistance, and to the subjects for their participation.

REFERENCES

1. James WPT. The epidemiology of obesity. In: Chadwick DJ, Cardew G, eds. The Origins and Consequences of Obesity. Chichester, United Kingdom: Wiley, 1996:1–16. (Ciba Foundation Symposium 201.)
2. Flegal KM, Carroll MD, Kuczmarski RJ, Johnson CL. Overweight and obesity in the United States: prevalence and trends, 1960–1994. Int J Obes 1998;22:39–47.
3. Grundy SM. Multifactorial causation of obesity: implications for prevention. Am J Clin Nutr 1998;67(suppl):563S–72S.
4. Willett WC. Is dietary fat a major determinant of body fat? Am J Clin Nutr 1998;67(suppl):556S–62S.
5. Lissner L, Heitmann BL. Dietary fat and obesity: evidence from epidemiology. Eur J Clin Nutr 1995;49:79–80.
6. Roberts SB, Pi-Sunyer X, Dreher M, et al. Physiology of fat replacement and fat reduction: effects of dietary fat and fat substitutes on energy regulation. Nutr Rev 1998;56(part 2):29–49.
7. Le Magnen J. Hyperphagie provoquee chez le rat blanc par l'alteration du mécanisme de satiété peripherique. (Hyperphagia provoked in the white rat by the alteration of peripheral mechanisms of satiety.) C R Séances Soc Biol Fil 1956;153:32–4 (in French).
8. Mugford RA. External influences in the feeding of carnivores. In: Kare MR, Maller O, eds. The chemical senses and nutrition. New York: Academic Press, 1971:25–50.
9. Rolls BJ, van Duijvenvoorde PM, Rowe EA. Variety in the diet enhances intake in a meal and contributes to the development of obesity in the rat. Physiol Behav 1983;31:21–7.
10. Triet D, Spetch ML, Deutsch JA. Variety in the flavor of food enhances eating in the rat: a controlled demonstration. Physiol Behav 1983;30:207–11.
11. Louis-Sylvestre J, Giachetti I, Le Magnen J. Sensory versus dietary factors in cafeteria-induced overweight. Physiol Behav 1984;32:901–5.
12. Rogers PJ, Blundell JE. Meal patterns and food selection during the development of obesity in rats fed a cafeteria diet. Neurosci Biobehav Rev 1984;8:441–53.
13. Clifton PG, Burton MJ, Sharp C. Rapid loss of stimulus-specific satiety after consumption of a second food. Appetite 1987;8:149–56.
14. DiBattista D, Sitzer CA. Dietary variety enhances meal size in golden hamsters. Physiol Behav 1994;55:381–3.
15. Pliner P, Polivy J, Herman CP, Zakalusn I. Short-term intake of overweight individuals and normal weight dieters and non-dieters with and without choice among a variety of foods. Appetite 1980;1:203–13.
16. Bellisle F, Le Magnen J. The structure of meals in humans: eating and drinking patterns in lean and obese subjects. Physiol Behav 1981;27:649–58.
17. Rolls BJ, Rowe EA, Rolls ET, Kingston B, Megson A, Gunary R. Variety in a meal enhances food intake in man. Physiol Behav 1981;26:215–21.
18. Rolls BJ, Rolls ET, Rowe EA, Sweeney K. Sensory specific satiety in man. Physiol Behav 1981;27:137–42.
19. Rolls BJ, Rowe EA, Rolls ET. How sensory properties of foods affect human feeding behavior. Physiol Behav 1982;29:409–17.
20. Spiegel TA, Stellar E. Effects of variety on food intake of underweight, normal-weight and overweight women. Appetite 1990;15:47–61.
21. Gallo AE. First major drop in food product introductions in over 20 years. Food Rev 1997;20:33–5.
22. Vinken AG, Bathalon GP, Sawaya AL, Dallal GE, Tucker KL, Roberts SB. Prediction of energy requirements in an adult population. Am J Clin Nutr (in press).
23. Block G, Hartmen AM, Dresser CM, Carroll MD, Gannon J, Gardner L. A data-based approach to diet questionnaire design and testing. Am J Epidemiol 1986;124:453–69.
24. Brozek J, Grande F, Anderson JT, Keys A. Densitometric analysis of body composition: revision and some quantitative assumptions. Ann N Y Acad Sci 1963;110:113–40.
25. Darling RC, Cournand A, Richards DW. Studies on the intrapulmonary mixing of gases. III. An open-circuit method for measuring residual air. J Clin Invest 1940;34:1417–26.
26. Siri WE. Body composition from fluid spaces and density: analysis of methods. In: Brozek J, Henschel A, eds. Techniques for measuring body composition. Washington, DC: National Academy of Sciences, 1961:223–4.
27. Brown KH. Complementary feeding in developing countries: factors affecting energy intake. Proc Nutr Soc 1997;56:139–48.
28. Lissner L, Levitsky DA, Strupp BJ, Kalkwarf HJ, Roe DA. Dietary fat and the regulation of energy intake in human subjects. Am J Clin Nutr 1987;46:886–92.
29. Kendall A, Levitsky DA, Strupp BJ, Lissner L. Weight loss on a low-fat diet: consequence of the imprecision of the control of food intake in humans. Am J Clin Nutr 1991;53:1124–9.
30. National Research Council. Recommended dietary allowances. 10th ed. Washington, DC: National Academy Press, 1989.
31. Committee on Diet and Health, National Research Council. Diet and health: implications for reducing chronic disease risk. Washington, DC: National Academy Press, 1989.
32. US Department of Agriculture and US Department of Health and Human Services. Nutrition and your health: dietary guidelines for Americans. 4th ed. Washington, DC: US Department of Agriculture and US Department of Health and Human Services, 1995. (Home and Garden Bulletin no. 232.)
33. US Department of Agriculture. The food guide pyramid. Hyattsville, MD: Human Nutrition Information Service, 1992. (Publication HG252.)
34. Kantor LS. Many Americans are not meeting food guide pyramid dietary recommendations. Food Rev 1996;19:7–15.

APPENDIX A

Complete listing of the initial 10 food groups and associated food types used in dietary variety analysis

Breakfast foods
1) High-fiber and granola cereals, *2*) highly fortified cereals, *3*) other cold cereals, *4*) cooked cereals, *5*) eggs, *6*) bacon, and *7*) sausage.

Lunch and dinner entrées
1) Hamburgers, cheeseburgers, and other ground beef items; *2*) beef, including on sandwiches; *3*) beef stew or pot pie; *4*) liver; *5*) pork; *6*) fried chicken; *7*) chicken or turkey; *8*) fried fish; *9*) tuna; *10*) shellfish; *11*) other fish; *12*) spaghetti, lasagna, or other pasta; *13*) pizza; *14*) mixed dishes with cheese; *15*) hot dogs; *16*) luncheon meats; *17*) vegetable and tomato soups; *18*) other soups; and *19*) chili with beans.

Sweets, snacks, and carbohydrates
1) Ice cream; *2*) sherbet or gelatin; *3*) frozen yogurt and ice milk; *4*) doughnuts, cookies, cake, and pastry; *5*) pies; *6*) chocolate candy; *7*) other candy; *8*) jelly, honey, and brown sugar; *9*) potato chips and corn chips; *10*) popcorn; *11*) French fries and fried potatoes; *12*) sweet potatoes and yams; *13*) other potatoes; *14*) rice; *15*) biscuits, muffins, and burger rolls;

The American Journal of Clinical Nutrition

Downloaded from ajcn.nutrition.org by guest on May 29, 2016

16) white breads, bagels, and crackers; *17*) dark breads, bagels, and crackers; and *18*) corn bread, corn muffins, and corn tortillas.

Condiments
1) Gravies made with meat drippings or white sauce, *2*) peanuts and peanut butter, *3*) margarine on bread or rolls, *4*) butter on bread or rolls, *5*) regular salad dressing and mayonnaise, *6*) diet salad dressing and diet mayonnaise, and *7*) butter, margarine, or other fat added to vegetables or potatoes.

Fruit
1) Apples, applesauce, and pears; *2*) bananas; *3*) peaches and apricots (canned, frozen, or dried); *4*) peaches, apricots, and nectarines (fresh); *5*) cantaloupe (in season); *6*) watermelon (in season); *7*) strawberries (fresh, in season); *8*) oranges; *9*) grapefruit; and *10*) other fruit including berries and fruit cocktail.

Vegetables
1) String beans and green beans; *2*) peas; *3*) other beans; *4*) corn; *5*) tomatoes and tomato juice; *6*) broccoli; *7*) cauliflower or Brussels sprouts; *8*) spinach (raw); *9*) spinach (cooked); *10*) mustard greens, turnip greens, and collards; *11*) cole slaw, cabbage, and sauerkraut; *12*) carrots or mixed vegetables with carrots; *13*) green salad; and *14*) other vegetables, including cooked onions and summer squash.

Energy-containing beverages
1) Orange juice or grapefruit juice; *2*) other fruit juices and fortified fruit drinks; *3*) whole milk and beverages with whole milk; *4*) 2% milk and beverages with 2% milk; *5*) skim milk, 1% milk, or buttermilk; *6*) regular soft drinks; *7*) beer; *8*) wine; and *9*) liquor.

Dairy products
1) Regular cottage cheese, *2*) low-fat cottage cheese and other low-fat cheeses, *3*) other cheeses and cheese spreads, *4*) flavored yogurt, and *5*) plain yogurt.

Breakfast food condiments
1) Milk added to cereal, and *2*) sugar added to cereal.

Beverage condiments
1) Nondairy creamer, *2*) milk, *3*) cream and half-and-half, and *4*) sugar.

The American Journal of Clinical Nutrition

Downloaded from ajcn.nutrition.org by guest on May 29, 2016