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Dietary Patterns Associated with a Low-Fat Diet in the National Health Examination Follow-up Study: Identification of Potential Confounders for Epidemiologic Analyses

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To identify systematically the nutrient and food group intakes associated with a low-fat diet, the authors used the detailed dietary information collected from 10,306 individuals aged 32–86 years in the 1982–1984 National Health Epidemiologic Follow-up Study. Intakes of vitamin C and percentages of calories from carbohydrates, dietary fiber, poultry, low-fat dairy products, fruits, vegetables, cereals, and whole grains were markedly higher, while intakes of protein, total fat, saturated fat, oleic and linoleic acids, cholesterol, sodium, all red meats, high-fat dairy products, eggs, nuts, white bread, fried potatoes, desserts, fats, and oils were much lower in the quartile with the lowest percentage of calories from fat. These dietary patterns associated with a low-fat diet were essentially constant across strata of age, sex, race, and socioeconomic status. This study suggests that individuals on a low-fat diet substitute certain carbohydrate-rich foods such as fruits and vegetables for fat. Given these associations between low-fat diets and other dietary factors independently associated with certain cancers, these dietary factors should be considered potential confounders in studies of dietary fat and these cancers. *Am J Epidemiol* 1993;137:916–27.

confounding factors (epidemiology); dietary fats; food habits

Consumption of dietary fat has been associated with cancer of the breast, colon, prostate, and ovaries in some studies, although the evidence is inconsistent (1–5). Reasons for this controversy have been widely discussed (6–8). One problem when studying dietary factors and disease is the complex interrelation between various nutrients and food groups (8,9). Thus, other nutrients and food groups could be confounding an association between dietary fat and disease if they are associated with fat intake and are also independent risk factors for the disease of interest. Dietary patterns associated with low-fat diets have been evaluated among clinical trial participants (10, 11), among control subjects in cancer studies (12), and in a small community (13). However, no studies have identified nutrients or food groups associated with fat intake in the general population.

This study evaluated the associations between various nutrients and food groups and a low-fat diet in the noninstitutionalized

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Abbreviations: NHANES I, First National Health and Nutrition Examination Survey; NHANES II, Second National Health and Nutrition Examination Survey; NHEFS, National Health Epidemiologic Follow-up Study.

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American population and examined the extent to which these associations are consistent across age, sex, race, and strata of socioeconomic status. In particular, we wanted to determine whether any nutrients or food groups were so highly associated with dietary fat that separation of the effects of dietary fat and these variables might be difficult in an epidemiologic study.

MATERIALS AND METHODS

The National Health Epidemiologic Follow-up Study (NHEFS) was a follow-up study of the First National Health and Nutrition Examination Survey (NHANES I) cohort. NHANES I data were collected between 1971 and 1975 from a national probability sample of the noninstitutionalized US population. Certain population subgroups, including persons living in poverty areas, women of childbearing age (25–44 years), and elderly persons (age 65 years or older) were oversampled. The 14,407 individuals who were between 25 and 74 years old when they first participated in the NHANES I study were eligible for inclusion in the study population for the NHEFS. Nearly 93 percent were successfully traced in the first follow-up of the cohort in 1982–1984. Of these, 84.9 percent (11,361) were living and 15.1 percent (2,022) were deceased; 92.6 percent (10,523) of the living subjects were interviewed (14).

As part of the 1982–1984 follow-up, dietary information was obtained by an in-person interview with all the living subjects. A food frequency questionnaire, comprised of 93 food items and 16 questions on food preparation and processing, was developed to assess all major macro- and micronutrients. Participants were asked to report their usual intake by number of times per day, week, month, or year over the previous year. Individuals who could not give frequencies of consumption for 10 or more of the 93 food items were excluded. Thus, data from 10,306 (90.7 percent) of the individuals traced and found alive in 1982–1984, 3,845 men and 6,461 women, were analyzed.

Information from the food and nutrient database associated with the Second National Health and Nutrition Examination Survey (NHANES II) (15–18), conducted between 1976 and 1980 and involving 12,200 24-hour recalls (19), was used to derive estimates of nutrient intake for the food frequency questionnaire used in the NHEFS. For each food frequency question in the NHEFS, appropriate food codes from the approximately 2,000 reported in the NHANES II 24-hour recalls were assigned, so that each NHEFS question corresponded to one or more NHANES II food codes. For instance, the question on orange juice in NHEFS would be assigned the codes for all of the different types of fresh and frozen orange juice which were reported by NHANES II participants. For six sex-age groups (men and women, aged 30-44, 45–64, and 65–86 years), the nutrient content per portion was calculated for each food frequency question, taking into account the relative frequency of reports in the 24-hour recalls for each food code assigned to the food frequency question. For instance, if 90 percent of the reports among men aged 30–44 years in NHANES II for orange juice were for frozen orange juice, while the remaining 10 percent of the reports were for fresh orange juice, then the nutrient content per portion of frozen orange juice for young men would be weighted 9/10, and that of fresh juice 1/10. To determine the size of a usual portion, median portion sizes for the six age-sex groups were estimated for each of the food codes, based on the actual portion sizes reported in the NHANES II 24-hour recall. Whenever there were 10 or fewer reports of intake of a food code in one of the six age/sex strata, the estimate for all ages combined was used. Micronutrients from supplements have not been included in the nutrient calculations.

To avoid excluding a large number of individuals in the analyses of a nutrient or a food group, age- and sex-specific median values were imputed when a response was missing for a food frequency question. This resulted in one or more imputed values for 22.8 percent of the individuals; 1,671 individuals (16.2 percent) had values imputed for one of the 93 food items, 423 (4.1 percent) had values imputed for two food items, and 252 (2.4 percent) had values imputed for 3–9 food items.

Percentage of calories from fat was divided into quartiles, based on the distribution in all 10,306 subjects, with cutpoints at 29.7, 33.5, and 37.0 percent. Whenever low-fat or high-fat group or quartile is mentioned in this paper, we are referring to the lowest and highest quartiles of percent of calories from fat, respectively.

The magnitude and direction of association between fat and nutrient and food group intake was evaluated with 1) Pearson's correlation coefficients with percent of calories from fat, 2) partial correlation coefficients with fat, adjusted for total calories, and 3) examination of the median nutrient or food group intake by each quartile of percent of calories from fat. Correlations with percent of calories from fat were examined because percent of calories from fat is a commonly used public health measure of dietary fat. The partial correlations were used to obtain an estimate of the association between fat and nutrients (or food groups) adjusted for calories. The partial correlation coefficient would, in this case, be equivalent to the result from a correlation of the fat residual with the nutrient (or food group) residual, in which the residuals are obtained from regressions of each variable on calories.

RESULTS

Some demographic characteristics of the NHEFS population used in the analyses are displayed in table 1. There were proportionally more women than men in the youngest age group. There were slightly fewer blacks among the men. There were no strong differences in family income and education among men and women.

Pearson's correlation coefficients between nutrients and percentage of calories from fat and partial correlation coefficients between fat and nutrients, adjusted for total calories, are displayed in table 2. The two correlations yielded similar patterns overall. Both meth-

TABLE 1. Demographic information on the 10,306 individuals who participated in the National Health Epidemiologic Follow-up Study in 1982–1984 and were included in the dietary analyses

	Men		Women	
	No.	%	No.	%
Total	3,845	37.3	6,461	62.7
Age at dietary interview (years)				
32–44	843	21.9	1,697	26.3
45–64	1,545	40.2	2,778	43.0
65–86	1,457	37.9	1,986	30.7
Race				
Black	436	11.3	942	14.6
White	3,362	87.4	5,463	84.6
Other	47	1.2	56	<0.1
Income (dollars)*				
0–9,999	880	22.9	1,994	30.9
10,000–19,999	910	23.7	1,380	21.4
20,000–34,999	998	26.0	1,448	22.4
≥35,000	857	22.3	1,060	16.4
Unknown	200	5.2	579	9.0
Education (years)†				
0–7	802	20.9	1,175	18.2
8–11	1,005	26.1	1,685	26.1
12–13	1,049	27.3	2,043	31.6
≥14	965	25.1	1,467	22.7
Unknown	24	<0.1	91	1.4

* Family (household) income (in 1982–1984 dollars).
† Education of head of household.

TABLE 2. *Pearson's correlation coefficients between nutrient intake and percentage of calories from fat, and partial correlations between fat and nutrients, adjusted for calories, National Health Epidemiologic Follow-up Study, 1982–1984*

Nutrients	Pearson's correlation coefficients with % kilocalories from fat	Partial correlation coefficients with fat, adjusted for total calories
Calories	0.09	
% kilocalories from carbohydrates	−0.66	−0.55
% kilocalories from proteins	0.36	0.37
Carbohydrates (g)	−0.18	−0.55
Protein (g)	0.25	0.44
Fat (g)	0.48	
Saturated fat (g)	0.47	0.88
Oleic acid (g)	0.49	0.95
Linoleic acid (g)	0.43	0.59
Cholesterol (mg)	0.38	0.43
Sodium (mg)	0.22	0.32
Potassium (mg)	−0.04	−0.14
Iron (mg)	0.07	0.04
Calcium (mg)	0.06	0.03
Phosphorus (mg)	0.09	0.04
Vitamin A (IU)	−0.07	−0.10
Thiamin (mg)	0.04	<0.01
Riboflavin (mg)	0.05	0.01
Niacin (mg)	0.10	0.05
Folate (μg)	−0.15	−0.28
Vitamin C (mg)	−0.31	−0.34
Dietary fiber (g)	−0.20	−0.29

ods showed strong negative correlations with percentage of calories from carbohydrates (Pearson's r = -0.66 and -0.55). Positive correlations above 0.30 were observed with percentage of calories from protein, total fat, saturated fat, oleic acid, linoleic acid, and cholesterol, while vitamin C was negatively correlated at -0.3. Both methods showed essentially no correlation with micronutrients, with the exception of vitamin C and sodium. Compared with the Pearson's correlation coefficients with percent of calories from fat, the partial correlation coefficients were more strongly positive for protein, saturated fat, linoleic acid, and oleic acid, and more strongly negative for carbohydrates.

Pearson's correlation coefficients between food groups and percentage of calories from fat, and partial correlations of food groups with total fat intake, adjusted for total calories, yielded very similar values (table 3). Few strong associations were noted with either method. The highest positive coefficients were seen for all red meats and fats and oils (Pearson's r = 0.39–0.45), and stronger negative correlations were observed for white meat/(white plus red meat) and all fruits (Pearson's r = -0.29 to -0.39). All three red meat categories as well as egg intake were positively correlated with both methods, while all fruit groups were negatively correlated. Vegetables were also negatively correlated with fat intake, but less strongly than were fruits. The subgroups of starches and dairy products showed positive and negative correlations with fat intake, but the combination of the subgroups in each case diluted the associations, resulting in an ap-

TABLE 3. Pearson's correlation coefficients between food groups* intake and percentage of calories from fat, and partial correlations between fat and food group intake, adjusted for calories, National Health Epidemiologic Follow-up Study, 1982–1984

Food groups	Pearson's correlation coefficients with % kilocalories from fat	Partial correlation coefficients with fat, adjusted for total calories
All red meat	0.41	0.45
Beef	0.26	0.26
Pork	0.19	0.17
Processed meats†	0.33	0.34
All white meat	−0.05	−0.06
Poultry	−0.04	−0.04
Fish and shellfish	−0.04	−0.05
White meat/(white + red meat)	−0.34	−0.29
All dairy‡	0.05	0.04
Lowfat/skimmed milk	−0.12	−0.11
Whole milk	0.15	0.15
Cheese, cream, and sour cream§	0.18	0.15
Eggs	0.29	0.28
All fruits‖	−0.38	−0.39
Citrus	−0.32	−0.32
Winter	−0.26	−0.26
Summer	−0.18	−0.19
All vegetables¶	−0.08	−0.11
Light green	−0.09	−0.11
Dark green	−0.10	−0.11
Yellow/red	−0.13	−0.13
All legumes	0.10	0.08
Peas and beans	−0.06	−0.09
Nuts#	0.19	0.18
Starches	−0.07	−0.12
Rice and pasta	−0.06	−0.10
Cereal**	−0.16	−0.17
Whole grain††	−0.15	−0.15
White bread	0.06	0.03
Fried potatoes	0.13	0.11
Other potatoes	0.06	0.04
Desserts	0.15	0.14
Alcohol‡‡	−0.27	−0.42
Fats and oils§§	0.41	0.39

* Servings per week.
† Liverwurst, sandwich and luncheon meats, hot dogs, meat spread, bacon, and pork sausage.
‡ None of the dairy dishes include additions to coffee or tea.
§ Cream, sour cream, half-and-half, and combination dishes such as macaroni and cheese.
‖ Citrus: oranges, tangerines, orange juice, grapefruits, and grapefruit juice; winter: apples, pears, and bananas; summer: peaches, nectarines, cantaloupe, watermelon, plums, and strawberries.
¶ Light green: Green peas and beans, green lima beans, string beans, okra, Brussels sprouts, summer squash, zucchini, yellow crookneck squash, green peppers, and leaf lettuce; dark green: broccoli, spinach, collards, and turnip greens; yellow/red: winter squash, acorn squash, butternut squash, hubbard squash, and pumpkin.
# Peanuts, peanut butter, and other nuts.
** Cold and hot cereal.
†† Cereals high in fiber, whole grain bread, and corn tortillas.
‡‡ Beer, wine, and liquor (drinks per week).
§§ Salad dressing, cheese sauce, white sauce, other thick gravies, butter, margarine, cream, sour cream, and half-and-half.

parent lack of association with the overall group.

Using natural log transformations of nutrients and food groups yielded similar Pearson's correlation coefficients with percent of calories from fat (not shown). The largest discrepancy compared with the results in tables 2 and 3 was observed for all fruits, which had a correlation coefficient with percent of calories from fat of -0.29.

Alcohol was negatively correlated with fat intake with both methods, and like protein and carbohydrates, the partial correlations adjusted for calories were larger than the correlation coefficients with percent of calories from fat. However, in general the two methods yielded similar patterns for both nutrients and food groups, and only percent of calories from fat is used as a measure of fat intake in the rest of this paper.

Table 4 shows the median intake of nutrients by quartile of percent of calories from fat. The pattern observed in table 4 was similar to that observed in tables 2 and 3. Median intake of total fat and cholesterol, as well as the three types of fat (saturated fat, oleic acid, and linoleic acid) were 65–86 percent higher in the high-fat compared with

TABLE 4. Median intake of nutrients by quartile of percent of calories from fat, National Health Epidemiologic Follow-up Study, 1982–1984

	Quartiles of % of calories from fat*				% difference†
	1	2	3	4	
Calories	1,377	1,450	1,505	1,554	12.9
% kilocalories from carbohydrates	57.4	52.2	48.4	42.7	−25.6
% kilocalories from proteins	14.6	15.4	15.9	16.8	14.8
Carbohydrates (g)	190	185	180	163	−14.3
Protein (g)	50.6	56.0	59.7	65.0	28.4
Fat (g)	39.9	51.1	58.8	68.9	72.8
Saturated fat (g)	13.3	17.2	20.2	24.2	82.7
Oleic acid (g)	14.0	18.4	21.7	26.0	86.1
Linoleic acid (g)	6.12	7.90	8.92	10.1	65.4
Cholesterol (mg)	215	270	304	366	70.0
Sodium (mg)	1,972	2,235	2,403	2,543	29.0
Potassium (mg)	2,551	2,529	2,511	2,447	−4.1
Iron (mg)	10.9	11.6	11.7	11.9	9.6
Calcium (mg)	536	556	565	573	6.9
Phosphorous (mg)	931	980	1,017	1,055	13.3
Vitamin A (IU)	7,639	7,484	7,193	6,560	−14.1
Thiamin (mg)	1.01	1.06	1.08	1.07	5.9
Riboflavin (mg)	1.38	1.44	1.46	1.47	6.5
Niacin (mg)	15.2	16.3	16.8	17.6	15.5
Folate (μg)	266	257	252	231	−13.3
Vitamin C (mg)	176	156	140	112	−36.3
Dietary fiber (g)	14.4	13.8	13.0	11.6	−19.3

* The quartile sample sizes are 2,572, 2,575, 2,577, and 2,582 persons for quartiles 1, 2, 3, and 4, respectively.
† Percent increase or decrease from the lowest to the highest quartile (100 × (Q_4 − Q_1/Q_1).

the low-fat quartile. Percent of calories from protein and total protein were 15 and 28 percent higher, while percent of calories from carbohydrates and total carbohydrates were 26 and 14 percent, lower, respectively, in the high-fat quartile. Compared with the lowest fat quartile, sodium was 29 percent higher in the high-fat quartile, while vitamin C and dietary fiber were 36 percent and 19 percent lower in the high-fat quartile, respectively. Other micronutrients showed differences that were less than 15 percent across quartiles of dietary fat.

The findings for nutrients were reflected in the food groups (table 5). Median intakes of all red meat and its subgroups, high-fat dairy products, nuts, white bread, fried potatoes, desserts, and fats and oils were approximately 100–300 percent higher in the high-fat quartile, while intakes of low-fat milk, poultry, proportion of all meat that was white, all fruit subgroups, yellow-red vegetables, cereals, and whole grain were approximately 40–100 percent lower in the high-fat quartile.

Median absolute intake varied by age and sex, with men having greater intakes of almost all foods and nutrients. Exceptions were fruits and vegetables, for which women had 10–20 percent higher absolute intakes than did men in all fat quartiles. Absolute intakes of vitamin C, vitamin A, cereal and whole grain were similar or greater in women than in men in the lower fat quartiles.

The last column in table 5 shows the relative difference between the median intake in the high- and low-fat quartiles as percent of the median intake in the low-fat quartile. The percent relative differences in intake of nutrients between the high- and low-fat quartiles were, in general, rather similar in men and women of all three age groups (32–44, 45–64, and 65–86 years of age), but young (age 32–44 years) and middle-aged (age 45–64 years) men were slightly

TABLE 5. Median intake of food groups* by quartile of percent of calories from fat, National Health Epidemiologic Follow-up Study, 1982–1984

Food groups	Quartiles of fat intake as % of total calories†				% difference‡
	1	2	3	4	
All red meat	4.3	6.3	7.8	9.8	127
Beef	2.0	3.0	3.0	4.0	100
Pork	0.3	0.5	1.0	1.0	300
Processed meats§	1.2	2.0	3.0	4.0	235
All white meat	3.3	3.3	3.0	2.8	−15.4
Poultry	2.0	2.0	1.0	1.0	−50.0
Fish and shellfish	1.3	1.4	1.3	1.3	−3.0
White meat/(white + red meat)	0.4	0.3	0.3	0.2	−47.9
All dairy‖	8.8	9.0	9.3	9.2	4.7
Lowfat/skimmed milk	1.2	1.0	0.3	0.0	−100
Whole milk	0.0	0.0	0.3	1.0	100
Cheese, cream, and sour cream¶	1.0	2.0	2.0	2.0	104
Eggs	2.0	3.0	3.0	4.0	100
All fruits#	21.5	18.2	15.2	10.8	−49.9
Citrus	8.0	7.0	5.9	3.2	−59.6
Winter	6.3	4.8	4.0	2.5	−60.2
Summer	2.5	2.4	2.0	1.5	−40.3
All vegetables**	18.6	18.7	18.0	16.5	−11.1
Light green	4.4	4.3	4.0	3.6	−18.9
Dark green	1.0	1.0	1.0	0.8	−25.0
Yellow/red	2.0	1.8	1.5	1.3	−37.5
All legumes	3.5	4.1	4.3	4.3	22.1
Peas and beans	2.5	2.5	2.5	2.3	−10.0
Nuts††	0.5	1.0	1.1	1.3	150
Starches	18.4	19.3	19.0	17.1	−7.0
Rice and pasta	11.2	12.0	11.9	10.5	−5.8
Cereal‡‡	3.0	3.0	2.3	1.3	−58.3
Whole grain§§	6.0	5.0	4.0	2.8	−54.2
White bread	3.0	4.5	6.5	6.0	100
Fried potatoes	0.2	0.3	0.5	0.8	255
Other potatoes	2.0	2.0	2.0	2.1	5.8
Desserts	1.0	3.0	3.0	3.0	200
Alcohol‖‖	0.2	0.2	0.2	0.1	−32.5
Fats and oils¶¶	8.1	11.0	14.0	16.0	96.5

* Servings per week.

† The cutpoints for the quartiles were: 29.7%, 33.5%, and 37.0% of calories from fat. The quartile sample sizes are 2,572, 2,575, 2,577, and 2,582 persons for quartiles 1, 2, 3, and 4, respectively.

‡ Percent increase or decrease from the lowest to the highest quartile: $(100 \times (Q_4 - Q_1)/Q_1)$.

§ Liverwurst, sandwich and luncheon meats, hot dogs, meat spread, bacon, and pork sausage.

‖ None of the dairy dishes include additions to coffee or tea.

¶ Cream, sour cream, half-and-half, and combination dishes such as macaroni and cheese.

\# Citrus: oranges, tangerines, orange juice, grapefruits, and grapefruit juice; winter: apples, pears, and bananas; summer: peaches, nectarines, cantaloupe, watermelon, plums, and strawberries.

** Light green: green peas and beans, green lima beans, string beans, okra, Brussels sprouts, summer squash, zucchini, yellow crookneck squash, green peppers, and leaf lettuce; dark green: broccoli, spinach, collards, and turnip greens; yellow/red: winter squash, acorn squash, butternut squash, hubbard squash, and pumpkin.

†† Peanuts, peanut butter, and other nuts.

‡‡ Cold and hot cereal.

§§ Cereals high in fiber, whole grain bread, and corn tortillas.

‖‖ Beer, wine, and liquor (drinks per week).

¶¶ Salad dressing, cheese sauce, white sauce, other thick gravies, butter, margarine, cream, sour cream, and half-and-half.

different. For instance, among young and middle-aged men, the percent relative differences between the high- and the low-fat quartiles in total protein and percent of calories from protein was 20–30 percent, while the same relative differences in the other age-sex groups were 13–14 percent. Percent relative differences between the high- and the low-fat quartiles for vitamin A, vitamin C, fiber, fruits, vegetables, and whole grain were noticeably lower among young and middle-aged men than among the other age-sex groups. For instance, the relative difference of fruit intake between the high- and low-fat quartiles among young and middle-aged men was 30 percent, while the relative difference between the two quartiles was 40–50 percent in the other age-sex groups.

These relative differences by age and sex appeared to be partly due to the presence of heavy consumers of alcohol among the young and middle-aged men. Because of the caloric content of alcohol, heavy drinkers would tend to fall in the lower percent of calories from fat quartiles and to produce dietary patterns that resulted from heavy drinking rather than from low levels of total fat intake. The data were reanalyzed in two ways: first, by excluding the 5 percent of the population with the highest beer consumption (10.5 drinks/week or more), the 5 percent with the highest wine intake (four drinks/week or more) and the 5 percent with the highest liquor consumption (7.5 drinks/week or more), and second, by excluding calories from alcohol in the calorie calculations. Quartile cutpoints for percent of calories from fat were recalculated, and median intakes of nutrients and food groups by fat quartiles were examined. In both instances, the dietary patterns for young and middle-aged men became more similar to those of old men and all women, although some of the differences in intake of protein, vitamin A, and fiber remained. Further analyses of these age-sex differences for protein, vitamin A, and fiber were complicated by sparse numbers. However, despite these differences, both approaches indicated that the main dietary patterns associated with a low-fat diet were essentially the same for men and women of all three age groups.

The median intake of nutrients and major food groups by fat quartile as well as the percent relative differences between the lowest and highest quartiles were evaluated by race and sex. Because there were proportionally more heavy consumers of alcohol among the white than among the black young and middle-aged men, the analyses by race were done excluding calories from alcohol in the calorie calculations. Patterns for black and for white men were essentially similar. Compared with white women, black women had 8–15 percent smaller relative differences across fat quartiles for carbohydrates, protein, total fat, all types of fat, cholesterol, and sodium, but 10 percent larger relative differences for vitamins C and A, fiber, folate, fruits, and vegetables.

Trends were also similar across quartiles of the two socioeconomic variables. When heavy drinkers of alcohol or calories from alcohol were excluded in the nutrient calculations, the largest relative differences were seen for total fat intake. In the low-income group, the relative difference for total fat between the high- and low-fat quartiles was 60 percent. In the high-income group, the relative difference between the two quartiles was 50 percent among men and 40 percent among women. Similarly, the relative differences between the high- and the low-fat quartiles of processed meats, high-fat dairy products, and vegetables were two to three times larger in the low- than in the high- income group.

As detailed in Materials and Methods, we used imputed values for persons with nine or fewer missing food frequency responses. Substituting the imputed values with zeroes did not change the above results. Trends were also similar across strata of smoking status and Quetelet index. Exclusion of 5,542 individuals who in 1982–1984 reported that a physician had ever diagnosed them with a chronic disease also resulted in similar patterns.

Table 6 shows categories of quartiles of percentage of calories from fat versus quar-

TABLE 6. Cross-classification of individuals (percent distribution) on quartiles of fat intake as percent of total calories versus quartiles of carbohydrate intake as percent of total calories and quartiles of total vitamin C intake, National Health Epidemiologic Follow-Up Study, 1982–1984

	Quartiles of fat intake as % of total calories*			
	1	2	3	4
Quartiles of carbohydrate intake as % of total calories				
1	2.9	2.7	4.4	15.0
2	2.0	4.1	10.1	8.8
3	3.4	10.7	9.7	1.2
4	16.8	7.5	0.8	0.0
Quartiles of vitamin C intake				
1	3.9	4.8	6.5	9.8
2	4.8	5.9	6.7	7.6
3	6.3	7.1	6.7	4.9
4	10.0	7.1	5.1	2.8

* The cutpoints for the quartiles were: 29.7%, 33.5%, and 37.0% of calories from fat. The quartile sample sizes are 2,572, 2,575, 2,577, and 2,582 persons for quartiles 1, 2, 3, and 4, respectively.

tiles of two other variables: percentage of calories from carbohydrates and absolute intake of vitamin C. If two variables are uncorrelated, one would expect to find 6.25 percent of the study population in each cell and 25 percent along each diagonal. However, for a variable as highly correlated with percent of calories from fat as percentage of calories from carbohydrates (Pearson's r = -0.66), over half of the population falls along the diagonal from the low-fat/high-carbohydrate cell to the high- fat/low carbohydrate cell. To separate the effect of percent of calories from carbohydrate from that of percent of calories from fat in an epidemiologic analysis, one would be interested in the part of the study population that falls into the cells that are not on the diagonal. In this case, 7.55 and 2.05 percent are located in the three corner cells farthest away from the diagonal. For vitamin C, which has a moderate correlation coefficient with percent of calories from fat (Pearson's r = -0.31), one third of the population falls along the diagonal with percent of calories from fat when these quartile cutpoints are used, while 13.5 and 12.8 percent fall into the three corner cells farthest away from the diagonal.

DISCUSSION

Median intakes of vitamin C, percent of calories from carbohydrates, dietary fiber, poultry, low-fat dairy products, fruits, vegetables, cereals, and whole grains were higher, while intakes of protein, total fat, saturated fat, oleic and linoleic acids, cholesterol, sodium, all red meats, eggs, high-fat dairy products, nuts, white bread, fried potatoes, desserts, and fats and oils were lower in the quartile with the lowest percent of calories from fat. These patterns were observed in all age and sex groups, with the similarity among age-sex groups becoming more apparent when the heaviest alcohol drinkers were excluded or when calories from alcohol were excluded in the nutrient calculations. The differences in nutrient and food group intakes between the highest and the lowest quartiles of percent of calories from fat varied somewhat by race, but the main patterns remained the same. The patterns were surprisingly consistent across strata of education and family income.

The size of the estimated median caloric intake suggested that the food frequency questionnaire underestimated the absolute intake to some extent. However, there was no indication that individuals in certain fat quartiles or of certain age-sex configurations underestimated their intake more than did others.

We did not include micronutrients from supplements in the nutrient calculations. Supplement users have higher intakes of micronutrients from diet than do nonusers in some (20–22), but not all (23–26), studies. If there is little difference in diets between supplement users and nonusers, incorporating the micronutrients from supplements would probably have resulted in similar patterns between fat and micronutrient intake. However, if supplement users have a higher intake of fruits and vegetables but a lower fat intake (22), then the vitamin A and vitamin C patterns with dietary fat would probably have been stronger if we had incorporated the nutrients from supplements in the nutrient calculations.

Our findings correspond in part to what was reported by two clinical trials and one community study. In the Woman's Health Trial (10), the low-fat group reduced the mean intake of red meat and high-fat dairy products and increased the mean intake of low-fat dairy products and, to some extent, fruit and vegetable intake, while there were only smaller increases in intakes of grain products and white meats. In a small intervention study from Finland (11), a decreased percentage of calories from fat was associated with lower intake of high-fat dairy products and pork, but higher intake of low-fat dairy products, beef, fruits, and to some degree, vegetables, while there was almost no change in intake of grain products. However, these two studies describe how individuals substitute calories from fat when they modify their diets in an intervention study, while our study describes what a low-fat diet consists of among individuals adhering to such a diet for an extended period. In a small Irish community study (13), however, individuals with a diet with more than 40 percent of calories from fat tended to eat more meat, milk, butter, and fruits, but fewer potatoes and bread. Further, Subar et al. (27), analyzing a 59-item food-frequency questionnaire from 20,143 individuals participating in the 1987 National Health Interview Survey found patterns associated with a low-fat diet that were comparable with those identified in this study, with higher intakes of fruits, vegetables, cereals, whole grains, low-fat dairy products, white meat, and associated nutrients and lower intakes of red and processed meats, high-fat dairy products, eggs, table fats, and desserts.

The associations we found between dietary fat and selected nutrients and food groups need to be kept in mind when evaluating the associations between low-fat diet and diseases. For instance, if one is studying the effect of percent of calories from fat on lung cancer incidence in the United States, our study suggests that a high percent of calories from fat is associated with low intakes of fruits, vegetables, vitamin C, and vitamin A. Since increased intake of fruits, vegetables, and carotenoids might be independently associated with a reduced risk of lung cancer (28, 29), these dietary components are potential confounders in the lung cancer study.

We observed a strong negative association between alcohol intake and percent of calories from fat among young women and all men. Because of this negative association between alcohol and dietary fat and because alcohol is known to increase the risks of certain cancers (30), alcohol is an obvious potential confounder when studying the association between a low-fat diet and these cancers.

Some of the described dietary patterns would not have been observed if we had used only a few broad food groups. For instance, while dairy products overall did not show any difference across quartiles of percent of calories from fat, low-fat dairy product intake was lower and high-fat dairy product intake was higher in the highest quartile. Likewise, by combining all starches or red and white meat we would expect to see a much smaller or no difference across fat quartiles of percent of calories from fat, obscuring the fact that intakes of fried potatoes, white bread, and red meat were higher, while intakes of whole grains, cereals, and white meat were lower in the high-fat quartile. This demonstrates the potential importance of obtaining detailed dietary information, instead of examining only broad food groups.

While controlling for other dietary variables is certainly possible in assessments of the effect of fat intake, the degree of correlation of some of these covariates could create serious difficulties with respect to statistical power. For example, if one were to separate the effects of percentage of calories from fat and a variable that was as highly correlated with it as percentage of calories from carbohydrates (Pearson's r = -0.66), data from over half of the population would be uninformative if quartile cutpoints were used. However, even if the effect of percentage of calories from fat were to be separated from a variable that was only moderately strongly correlated with it, such as vitamin C (Pearson's r = -0.31), data from approximately one third of the population would not contribute any information if these quartile cutpoints were used. Further, only a very small percentage would be found in the low-low or the high-high group in each case. Thus, attempting to separate these effects by using quartile cutpoints in a small study might create serious problems with respect to statistical power.

The advantages and disadvantages of various methods used to control for calories have been widely discussed (31–35). Most of the analyses in this study were presented using the traditional nutritional measure, percent of calories from fat. With the exception of absolute intake of macronutrients, partial correlation coefficients between total fat and other nutrients and food groups controlled for calories were very similar to the Pearson's correlation coefficients between percent of calories from fat and the same nutrients and food groups. Subar et al. (27) also found similar correlations between the two methods and have investigated this in further detail.

The study population in NHANES I contained a large proportion of older individuals, women of childbearing age, and individuals living in poverty areas. We found no striking differences across age, sex, race (black/white), or strata of socioeconomic status. Thus, our findings are probably applicable to population-based studies of low-fat diet and disease in at least the non-Hispanic part of the US population.

In conclusion, we found that a low-fat diet in the general population was consistently associated with intake of specific nutrients and food groups. None of the estimated correlations were high enough to make assessment of independent effects impossible. However, some associations were strong enough to severely influence issues of statistical power and to make assessments of independent effects at the extremes of exposure essentially impossible. The patterns were basically constant across age, sex, race, and strata of socioeconomic status, suggesting that these variables are potential confounders in studies of dietary fat and certain cancers, no matter what age, sex, racial or socioeconomic status subgroup is under study.

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