# Nutrient Databases for Food Frequency Instruments

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## ABSTRACT

The food frequency questionnaire (FFQ), as a result of continued development beginning in the 1950's, has become the main-stay for nutritional epidemiology for a variety of reasons. The FFQ consists of two basic parts: a food list and frequency responses. The creation of a FFQ should involve pretesting to design a form specific to the target population. FFQ's can be reasonably reproducible and valid for both specific foods and nutrients. Testing of the FFQ, especially at the food level, provides useful insight into the ability of the form to provide adequate dietary information. The tool may be adapted to obtain dietary information more efficiently under a variety of situations. The FFQ has been used to successfully predict disease.

This presentation will briefly review the development of Food Frequency Questionnaire's (FFQ's) and more extensively describe the development and refinement of the Harvard/Willett food frequency questionnaire. With the results of validation studies conducted over the last 10 years, the form has been continuously refined to improve its quality and has been used to test numerous hypotheses relating diet and disease. Two recent studies clearly demonstrate that FFQs are capable of prospectively relating diet to disease. This work substantiates why FFQ's have become a mainstay for nutritional epidemiology.

The origins of the FFQ occurred in 1940's when Burke developed a detailed dietary history interview that evaluated an individual's usual diet through three methods: a 24 hour recall, a 3 day diet record, and a checklist of foods consumed during the past month(1). This checklist was apparently the first example of a FFQ, and was further developed in the 50's by Stefanik and Trulson, and others as outlined on the slide (2-5). At this time the American Public Health Association through a committe report called for investigators to find simple methods by which dietary data could be obtained quickly and inexpensively to provide nutritional information on a large number of subjects. This was deemed necessary to improve insight into the ever growing public health concerns in our country -- cancer and heart disease. In the early seventies there was skepticism concerning the use of FFQ's in predicting disease but with improved questionnaire formats and more studies reporting the usefulness of the form, interest has returned (6). FFQ's have now become widely accepted as a tool by which nutritional information can be obtained from large numbers of subjects necessary to investigate diet and disease risks.

| Investigator | Year | Tool |
|---|---|---|
| Burke | 1947 | Detailed History |
| Stephanik & Trulson | 1962 | FFQ |
| Heady | 1961 | FFQ |
| Weihl & Reed | 1960 | FFQ |
| Marr | 1971 | FFQ |

Our work began in the late 70's under the direction of Walter Willett and with the help of Jelia Witschi, a registered dietitian from the Harvard School of Public Health. A FFQ consists of 2 basic parts: (1) a list of foods and (2) a set of frequency response options used to indicate how often each food is consumed during a specified period of time. The objective is to rank individuals according to food and nutrient intake and to characterize food intake over an extended period. Usual intake is more relevant when studying diet and most diseases than today's or yesterday's food intake. To accomplish this, a long list of foods that contained significant amounts of the nutrients of interest was created. Second, a small scale pilot study was com-

pleted to assist in identifying infrequently eaten foods, which were eliminated, bringing the number of foods to 99. Third, the form was pretested to see which foods best predicted the nutrients of interest. This 99-item form was mailed to 2000 randomly selected Nurses Health Study subjects. 87% returned the form. Nutrient intake calculated from the form was used as the dependent variable in a step-wise multiple regression equation to determine which foods best predicted the nutrients of interest.

**Vitamin C Intake**

| Foods Most Predictive of Between Person Variation | Cumulative $R^2$ |
|---|---|
| Supplements | 0.91 |
| Orange Juice | 0.93 |
| Multivitamins | 0.94 |
| Fruit Punch | 0.96 |
| Spinach, Greens | 0.96 |
| Berries | 0.96 |
| Brussel Sprouts | 0.96 |

For example, 96% of the between-person variance, what one person eats versus another, in Vitamin C intake is explained by 7 foods. As a result of the compilation of this data, it was determined that 61 foods plus multivitamin usage accounted for at least 80% of the between-person variation in the specified 18 nutrients analyzed.

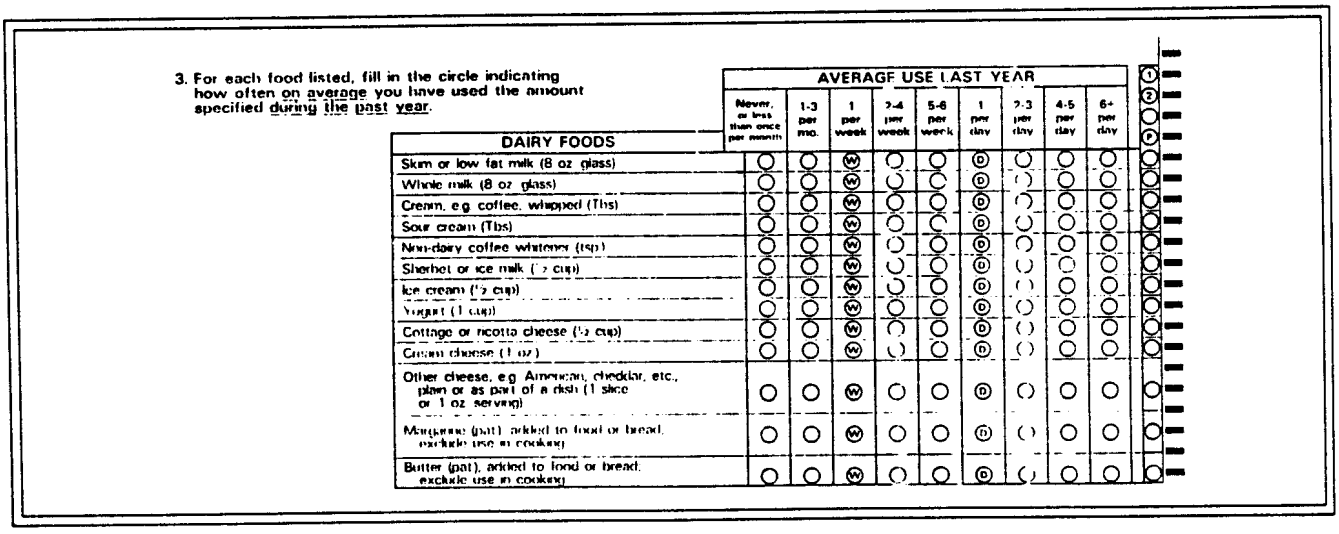
The 1980 FFQ that was distributed to over 100,000 women between the ages of 34 to 50 years in 11 US states contained 61 foods separated into 6 groups - dairy; fruits; vegetables; meats; sweets, baked goods, and cereals (as 1 group); and a miscellaneous group. Each food was assigned a specified portion using natural units when possible (ie slice of bread, 1 egg, glass of milk, 1 apple, 1 pat of margarine). The subjects were also supplied with 9 frequency responses by which to identify how often they ate the specified portion of food. The frequency responses range from never to 6 plus per day. This allows for subjects to answer how often they eat infrequent foods like liver as well as margarine or butter. The subjects were asked to describe their usual intake of these foods over the past year. There were also several special features of the form. The subjects were asked to identify the type of fat used for frying and cooking, the type of margarine and cereal, and amounts of bran, and sugar added to foods. Also, multivitamin and vitamin A,C and E use was obtained.

This FFQ provided our first large dietary data set, and was the object of our initial reproducibility and validity studies. Over the subsequent 10 years, other forms representing expansion, refinements, and modifications for specific populations have been created. There are 12 versions today and it has been translated into Spanish for Mexican and Latin American studies, French, Italian, and Greek.

What did we find?

Data obtained by a FFQ can be used in several ways. The actual frequency or number of times a food or food group is consumed might be of interest. Another is the nutrient scores calculated by summing the total of the product of the frequency of consumption of the foods by their nutritional content of a specified or assumed portion.

The first tests of the usefulness of the 1980 FFQ were done at the nutrient level as part of a substudy of the large prospective study mentioned. Reproducibility studies designed to see how well the form per-



3. For each food listed, fill in the circle indicating how often on average you have used the amount specified during the past year.

| DAIRY FOODS | Never, or less than once per month | 1-3 per mo. | 1 per week | 2-4 per week | 5-6 per week | 1 per day | 2-3 per day | 4-5 per day | 6+ per day |
|---|---|---|---|---|---|---|---|---|---|
| Skim or low fat milk (8 oz glass) | | | | | | | | | |
| Whole milk (8 oz glass) | | | | | | | | | |
| Cream, e.g. coffee, whipped (Tbs) | | | | | | | | | |
| Sour cream (Tbs) | | | | | | | | | |
| Non-dairy coffee whitener (tsp) | | | | | | | | | |
| Sherbet or ice milk (½ cup) | | | | | | | | | |
| Ice cream (½ cup) | | | | | | | | | |
| Yogurt (1 cup) | | | | | | | | | |
| Cottage or ricotta cheese (½ cup) | | | | | | | | | |
| Cream cheese (1 oz) | | | | | | | | | |
| Other cheese, e.g. American, cheddar, etc., plain or as part of a dish (1 slice or 1 oz serving) | | | | | | | | | |
| Margarine (pat), added to food or bread, exclude use in cooking | | | | | | | | | |
| Butter (pat), added to food or bread, exclude use in cooking | | | | | | | | | |

**Summed total daily cholesterol calculations**

| | Nurses Scores | Weighted Daily Freq. | x | Nutrient Portion |
|---|---|---|---|---|
| Eggs (1/day) | 274.0 mg = | 1 | x | 274.0 |
| Milk (2-3/day) | 82.8 mg = | 2.5 | x | 33.0 |
| Ice Cream (5-6/weeks) | 23.6 mg = 380.1 mg = | .8 Summed Total Daily Cholesterol | x | 29.5 |

formed when it was repeated, and the validation studies, designed to see how well the form did when it was compared to other dietary methods, were conducted (7). 28 days of diet records were collected from 194 subjects in the Greater Boston Area. The days were spaced evenly throughout the year to acquire 7 days from each of the seasons. At the end of the year of diet record keeping the FFQ was readministered to the women.

The results of these studies are shown on the next few slides. Pearson correlation coefficients for a reliability study, comparing Questionnaire 1 to Questionnaire 2 (Q2) ranged from 0.52 for Vitamin A without supplements to 0.71 for sucrose and produced a mean of 0.61 for 15 nutrients. Correlation coefficients of nutrient reproducibility studies are often between 0.5 and 0.7. Though these values may seem low compared to measurements made in a controlled laboratory enviroment they are comparable to biological measurements such as serum cholesterol or blood pressure taken over time.

The validity correlations shown here report the comparison of Q2 which reflects the average nutrient intake over the last year, the year of diet record keeping, with the mean nutrient intake from the diet records. They ranged from 0.36 for Vitamin A to 0.75 for Vitamin C . When we ranked individuals intake from the FFQ and the diet records into quintiles only 3% were extremely misclassified. This clearly shows the ability of the form to rank individuals into high versus low intake groups, the primary objective of nutritional epidemiologists. Once subjects are separated into high versus low intake groups their risk to a particular disease can be assessed.

What did we learn and how did we modify the form?

First, the form was converted to an optically scannable form. Our original form was a self administered mailed form which required key punching. Optical scanning decreased our coding and data entry costs.

Secondly, the form was expanded from 61 to 116 food items (8). Foods that had been collapsed or grouped together on the form were itemized separately to provide the subjects with more simple clear questions. We added back some foods that were important sources of nutrients of interest even though they did not independently contribute to between-person variation in nutrient intake in stepwise multiple regression. Four foods were added after analysis of the food records showed that they contained sources of nutrients that contributed to the absolute intake of the population. They were mixed vegetables, tomato sauce, other fruit juices and English muffins, bagels, and rolls as one group.

The expanded form was completed in 1984 four years after the first by the same subjects that had completed the original FFQ and diet records. The 61 item form had accounted for 51-97% of the nutrients consumed in the diet records. The expanded version accounted for 86-99%. Correlations comparing the revised and the original questionnaire completed by the Boston area subjects four years later ranged from 0.44 for total carbohydrate to 0.62 for vitamin C including supplements. This shows that the FFQ can provide useful information about nutrient intakes in the past.

**Percentage of Intake Accounted for by Foods on FFQ's**

| *Nutrient* | *61-Item FFQ* | *116-Item FFQ* |
|---|---|---|
| Total Calories | 69 | 93 |
| Protein | 77 | 95 |
| Total fat | 70 | 96 |
| Saturated fat | 75 | 96 |
| Monounsaturated fat | 72 | 96 |
| Cholesterol | 85 | 97 |
| Total carbohydrate | 61 | 90 |
| Crude fiber | 64 | 86 |
| Sucrose | 78 | 92 |
| Total vitamin A | 77 | 96 |
| Vitamin C | 84 | 93 |
| Vitamin B1 | 81 | 95 |
| Vitamin B2 | 85 | 95 |
| Vitamin B6 | 97 | 99 |
| Calcium | 77 | 94 |
| Iron | 75 | 93 |
| Mean | 75 | 94 |

Thirdly, an open-ended section to the questionnaire where subjects could report foods that were eaten weekly that were not asked on the FFQ was added. It was important to evaluate the contribution not only of the new additional foods section but also the other open-ended questions stated earlier, such as the types of oil, cereal, and multivitamin usage primarily because open-ended sections require additional coding steps and increase costs. This was done at the same time as the study just mentioned where the FFQ's were completed four years later. To investigate this question, nutrient intakes were computed from the FFQ's with and without the open-ended questions being included into the analysis and were compared to the diet record intakes. Only modest increases in correlations due to the addition of the open-ended questions in some of the nutrients were found. None of the changes were statistically significant. Although these results show little effect in the estimation of nutrient intake and the open-ended questions are costly and time consuming to process, caution should be taken when considering the removal of these questions from the form. These sections may provide important information in a more complex or heterogeneous population. A major limitation of FFQ's is that the food listing is fixed so the option for subjects to provide additional information maybe well worth the cost.

**Pearson Correlations between diet records and 116-Item FFQ**

| *Nutrient* | *No Deletion* | *Open-ended sections deleted* |
|---|---|---|
| Protein | 0.52 | 0.53 |
| Total fat | 0.54 | 0.54 |
| Saturated fat | 0.52 | 0.52 |
| Polyunsaturated fat | 0.58 | 0.58 |
| Monounsaturated fat | 0.48 | 0.47 |
| Cholesterol | 0.57 | 0.57 |
| Total carbohydrate | 0.61 | 0.61 |
| Crude fiber | 0.56 | 0.55 |
| Sucrose | 0.45 | 0.45 |
| Total Vitamin A | 0.44 | 0.38 |
| Vitamin C | 0.54 | 0.53 |
| Vitamin B1 | 0.58 | 0.52 |
| Calcium | 0.56 | 0.50 |
| Phosphorus | 0.51 | 0.50 |
| Potassium | 0.53 | 0.53 |
| Iron | 0.55 | 0.42 |

Fourthly, the controversial issue of portion sizes on the form was addressed. The Harvard/Willett FFQ is termed a semiquantitative FFQ because it specifies typical portion sizes. A pure FFQ would not request subjects to provide information on portion sizes. Other forms of FFQ's ask subjects to estimate their usual portion sizes. To look at this issue, the number of times that 66 food were eaten and the portion size on each occasion during the four weeks of diet records in the Boston area subjects were determined (9). For each food, total population variance in portion size was separated into within- and between-person components. A large within-person variance would indicate that subjects do not consistently eat the same portions and a large between-person variance would indicate that an individual might eat the same portion but that portion is not eaten often by other people. For all but 7 food items the within-person (intraindividual) variation was higher than the between-person (interindividual) variation. Foods with a high within-person variation also tended to have a high between-person variance. This data suggests that describing a "usual" portion size maybe a difficult thing for subjects to do since they do not eat the same portion. A portion size that at least approximates a population's norm identified through pilot testing at least will add clarity to the food frequency question. It will require that subjects calculate frequencies based on the specified portion and this may add complexity too. But adding the portion information allows for quantitative food and nutrient data to be obtained.

In a general population sample involving 97 subjects nutrient intakes derived from a FFQ without serving sizes for foods that do not come in natural units and from the same FFQ plus portion size information obtained during an extensive interview were both compared with intakes calculated from 7 day diet records (10). Correlations of log nutrient intakes for calories and macronutrients showed very slight increases when portion size information was used. After adjustment for total energy intake, there was essentially no improvement using the additional portion size data. There was no pattern of improvement for micronutrients. These data suggest that additional portion size information does not necessarily increase the validity of estimates obtained from a SFFQ alone.

The results reported above were based on reproducibility and validity studies at the nutrient level. We have also completed reliability and validity studies of the FFQ at the food level. To evaluate reproducibility at the food level, we compared the 99 food-item pilot FFQ completed by 1497 subjects with their responses

on the 61 item FFQ that was completed 9 months later (11). Correlations were highest for beverages with a correlation of 0.7 and ranged from 0.6 - 0.7 for foods eaten frequently and from 0.34-0.45 for foods eaten infrequently. In the 1980 study when the first and second FFQ were compared the reproducibility correlations ranged from 0.24 for fruit punch to 0.93 for beer. The mean correlation was 0.57. For 23% of the food items the correlation coefficient was greater or equal to 0.70, and for 73% of the foods it was greater or equal to 0.5. People tend to report well what they eat often and less well what they eat less often.

To evaluate validity at the food level, the original FFQ and the diet records were compared. To do this, the foods coded from the diet records were grouped to correspond with a food on the questionnaire (12). For example 146 diet record meat codes represented the two meat items on the FFQ, 10 codes were compressed to correspond with skim or lowfat milk . The amounts of the foods reported in the diet records were converted into the amounts specified on the questionnaire. For each subject we determined the mean daily amount of food consumed during each of the 4 weeks of diet records and the mean daily amount for the 4 full weeks of recording. Pearson correlation coefficients between the second FFQ and the diet records corrected for within- versus between-person variance ranged from 0.17 for yellow squash to 0.94 for beer. Subjects tended to overestimate consumption of some foods on the FFQ. In comparing the absolute amounts of each food estimated by the FFQ and the diet records it was found that butter, whole milk, eggs, processed meats and cold breakfast cereal were underestimated by 10-30% on the FFQ. On the other hand certain foods were overestimated by at least 50% They consisted of a number of fruits and vegetables, skimmed or lowfat milk, yogurt, and fish. This suggests that people over-report consumption of "healthy" foods and underestimate those considered "undesirable".

In general this level of reproducibility and validity testing at the food item level shows the ability of the FFQ to document and quantify intakes. It also allows insight to be gained into why certain foods or nutrients have lower or higher correlations than others. This methodology will not be reviewed here. However, for example, from investigating the form at the food level we have separated the spinach question on the form into 2 separate items, and have separated carrots into separate raw and cooked questions.

| Underestimated 30% | Overestimated by 10 - by at least 50% |
|---|---|
| Butter | Some Fruits and Vegtables |
| Whole Milk | Skimmed or Lowfat Milk |
| Eggs | Yogurt |
| Processed Meat | Fish |
| Cold Breakfast Cereals | |

In 1986 we reevaluated the reproducibility and validity of our expanded and refined FFQ which incorporated all of our changes to improve clarity of the form. The FFQ was evaluated in a group of 127 men and 197 women from the Greater Boston area. The women's data is not available at this time. For the men's study reproducibility of the FFQ completed one year apart ranged from 0.56 for polyunsaturated fat to 0.80 for vitamin C (13). The de-attenuated correlation coefficient or rather those corrected for the error due to within-person variability in diet records, between the questionnaire and the diet records ranged from 0.37 for polyunsaturated fat to 0.92 for vitamin C. The average correlation was 0.68.

As has been stated, a primary purpose of the FFQ is to be able to rank individuals into high and low intake groups to predict disease risks. It is best to evaluate this capacity in prospective studies to avoid the bias that might exist in case control studies. Even with prospective studies, caution must be used in interpreting these results because failure to find a relationship may simply be due to an inappropriate interval of time between FFQ's and the diagnosis of the disease. Absence of an expected association should not automatically be interpreted as the fault of the form.

We have conducted 2 studies which validate the use of the FFQ at the disease level by predicting strongly suspected associations. In 1980 when diet information was gathered from the 100,000 women, medical information was also obtained which has allowed prospective documentation of diet and disease risks. By 1986, 150 cases of colon cancer were documented (14). After adjusting for total energy intake, animal fat was positively associated with the risk of colon cancer. When subjects were separated into quintiles the relative risk for the highest as compared to the lowest group was 1.89.

In a second prospective study 52,000 men completed a 131 item FFQ in 1986. 7,248 participants underwent colonoscopy or sigmoidoscopy during a 2 year period. After adjusting for total caloric intake, red meat and saturated fat were positively associated with risk of adenomas of the large bowel and fiber intake from vegetables, fruits, and grains was strongly related to decreased risk (15).

In conclusion, the FFQ is an established nutritional tool that can be used with large numbers of subjects to acquire reproducible and valid food and nutrient information to test disease risks.

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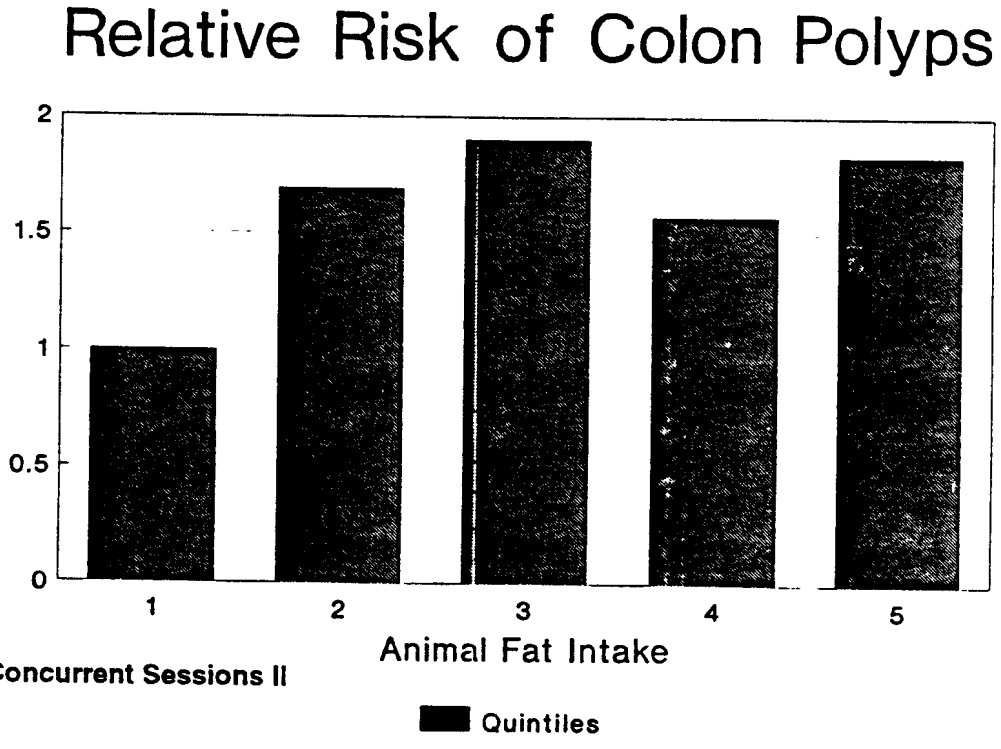
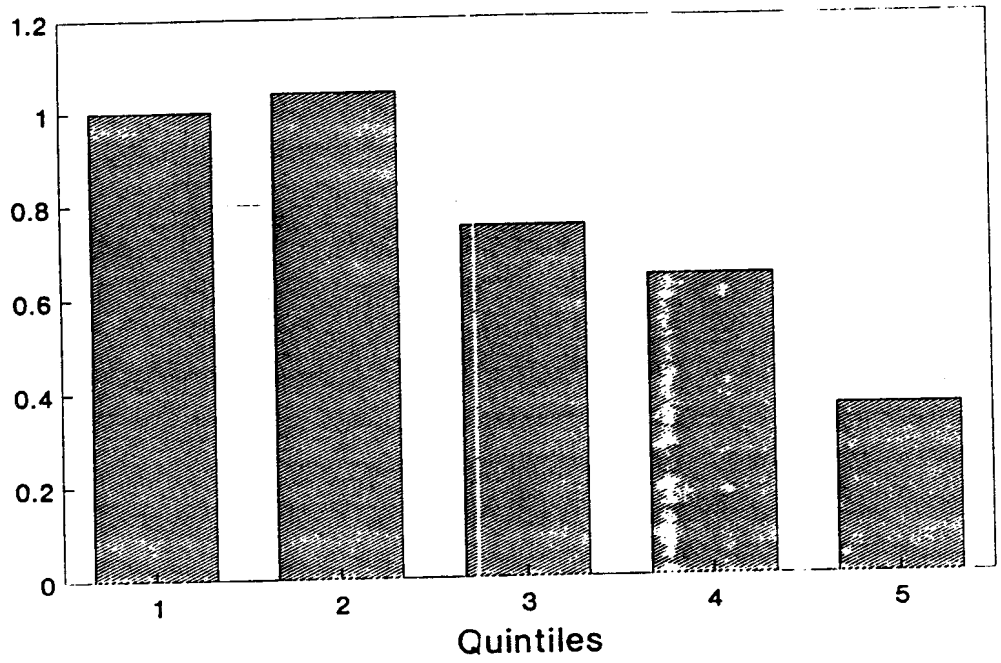
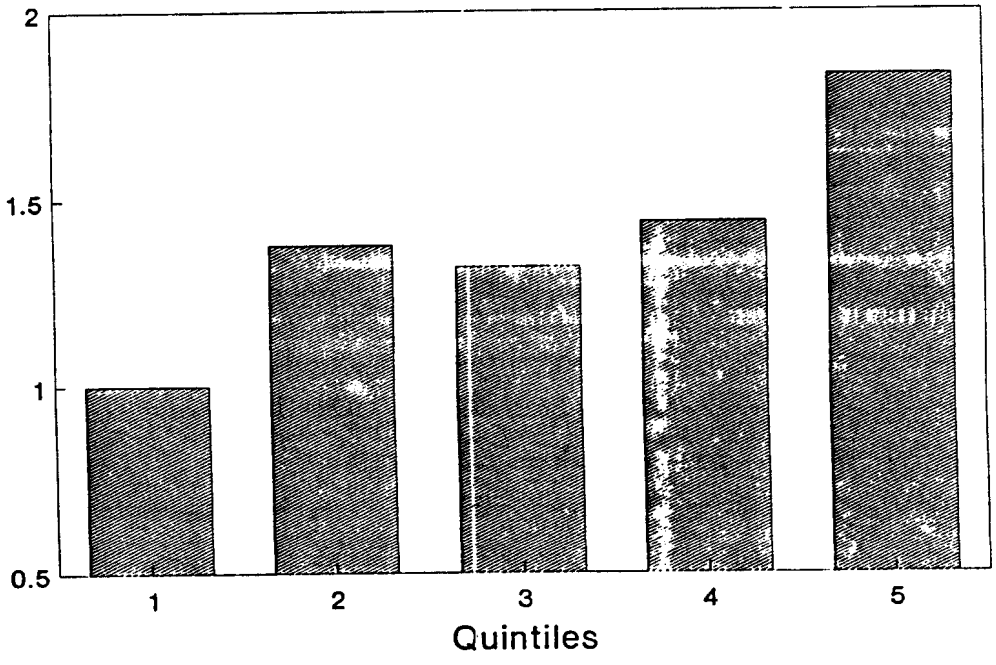


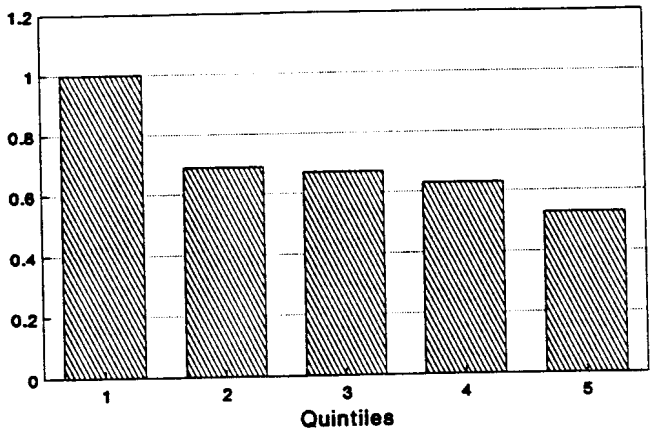
# Dietary Fiber

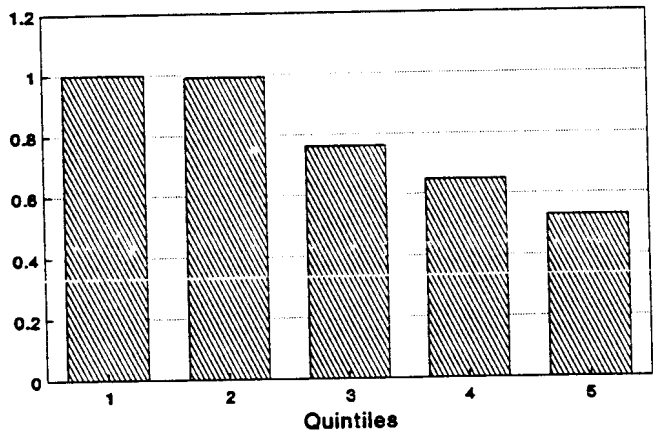


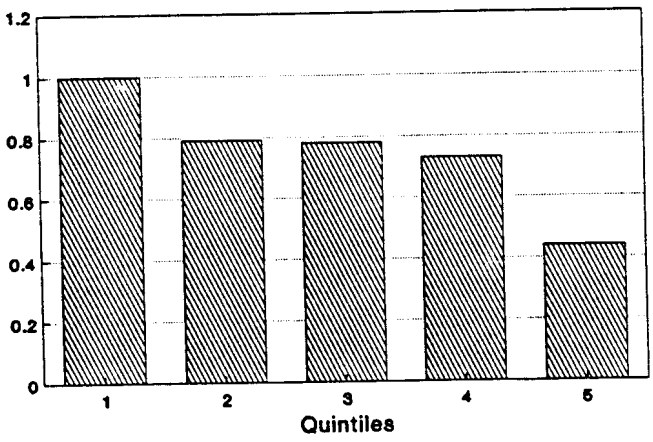

# Red Meat/Chicken & Fish




p value, test for trend = 0.02


Fruit Fiber
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
Quintiles


Vegetable Fiber
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
Quintiles


Cereal Fiber
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
Quintiles