ORIGINAL INVESTIGATION

Dietary Fiber Intake and Reduced Risk of Coronary Heart Disease in US Men and Women

The National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study

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Background: Prospective studies suggest that dietary fiber intake, especially water-soluble fiber, may be inversely associated with the risk of coronary heart disease (CHD).

Methods: We examined the relationship between total and soluble dietary fiber intake and the risk of CHD and cardiovascular disease (CVD) in 9776 adults who participated in the National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study and were free of CVD at baseline. A 24-hour dietary recall was conducted at the baseline examination, and nutrient intakes were calculated using Food Processor software. Incidence and mortality data for CHD and CVD were obtained from medical records and death certificates during follow-up.

Results: During an average of 19 years of follow-up, 1843 incident cases of CHD and 3762 incident cases of CVD were documented. Compared with the lowest quartile of dietary fiber intake (median, 5.9 g/d), participants in the highest quartile (median, 20.7 g/d) had an adjusted relative risk of 0.88 (95% confidence interval [CI], 0.74-1.04; *P*=.05 for trend) for CHD events and of 0.89 (95% CI, 0.80-0.99; *P*=.01 for trend) for CVD events. The relative risks for those in the highest (median, 5.9 g/d) compared with those in the lowest (median, 0.9 g/d) quartile of water-soluble dietary fiber intake were 0.85 (95% CI, 0.74-0.98; *P*=.004 for trend) for CHD events and 0.90 (95% CI, 0.82-0.99; *P*=.01 for trend) for CVD events.

Conclusion: A higher intake of dietary fiber, particularly water-soluble fiber, reduces the risk of CHD.

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EPIDEMIOLOGIC STUDIES of diet and heart disease have strongly suggested that dietary fiber intake is related to a lower risk of coronary heart disease (CHD). A recent review[1] identified 9 prospective studies that examine the relationship between dietary fiber intake and risk of CHD. Of these 9 studies, 7 found a significantly lower risk of CHD among those consuming greater amounts of dietary fiber. However, only 5 large epidemiologic studies,[1-5] all conducted in special populations, have examined the relationship between water-soluble fiber and risk of coronary disease prospectively. The results of these studies have been inconsistent, and only 1[2] of the 5 studies reported a significant inverse relationship between water-soluble fiber intake and risk of CHD after adjustment for established cardiovascular disease (CVD) risk factors.

Soluble fiber has been shown to decrease serum cholesterol concentration, especially low-density lipoprotein cholesterol concentration, without affecting the concentration of high-density lipoprotein cholesterol.[6] While these effects are modest, they may play a role in the apparent protective effect of fiber on the risk of coronary disease.[7] Epidemiologic studies[8] have also suggested an important role for dietary fiber in glycemic control and in the prevention of hyperinsulinemia and weight gain. We took advantage of the large sample size and the prolonged follow-up experience of participants in the National Health and Nutrition Examination Survey I (NHANES I) Epidemiologic Follow-up Study to examine the relationship of dietary fiber intake to subsequent risk of CVD in a nationally representative sample of the US noninstitutionalized population.

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METHODS

STUDY POPULATION

The NHANES I used a multistage, stratified, probability sampling design to select a representative sample of the US civilian noninstitutionalized population aged 1 to 74 years.[9,10]

Certain population subgroups, including those with a low income, women of childbearing age (25-44 years), and elderly persons (≥65 years), were oversampled. The NHANES I Epidemiologic Follow-up Study is a prospective cohort study of NHANES I participants who were aged 25 to 74 years when the survey was conducted between 1971 and 1975. Of the 14 407 persons in this age range at baseline, we excluded 3059 NHANES I augmentation survey participants for whom the study protocol did not include collection of dietary information, 45 persons who were missing gram amounts of food eaten, and 1132 persons who had a self-reported history of myocardial infarction, heart failure, or stroke at baseline or had used medication for heart disease during the preceding 6 months. Among the remaining participants, 395 (3.9%) were lost to follow-up, leaving a total of 9776 participants who contributed 161 352 person-years of experience.

MEASUREMENT

Baseline data collection included administration of medical history and dietary assessment questionnaires and conduct of a standardized medical examination, laboratory tests, and anthropometric measurements.[9,10] The dietary assessment included conduct of a single 24-hour dietary recall by trained NHANES I personnel using a standardized protocol and 51 three-dimensional models to estimate portion size. Dietary intake of total and water-soluble fiber was not available in the original NHANES I nutrient database but was estimated using the ESHA food processor nutrient database.[11] Each unique food of a listing of the 3481 foods recorded during NHANES I data collection was matched to a corresponding food item listed in the ESHA Food Processor nutrient database by name and available nutrient content.[11] Participants' dietary intake of total and water-soluble fiber (in grams per 24 hours), saturated fat (in grams per 24 hours), and total calories (energy) (in kilocalories per 24 hours) were calculated. A reliability analysis was conducted to evaluate correspondence between NHANES I and ESHA nutrient databases. Intraclass correlation coefficients for nutrient intakes derived using NHANES I and ESHA food composition databases ranged from 0.85 to 0.98.[12] Blood pressure, body weight, and height were obtained using standard protocols.[9] Frozen serum samples were sent to the Centers for Disease Control and Prevention for measurement of serum total cholesterol levels. The baseline questionnaire on medical history included questions about selected health conditions and medications used for these conditions during the preceding 6 months. Data on educational level, physical activity, and alcohol consumption were obtained by interviewer-administered questionnaires. Information on smoking status was obtained for 6913 participants who underwent a more detailed baseline examination.[9,10] For the remaining study participants, information on smoking status at baseline was derived from responses to questions on lifetime smoking history obtained at their follow-up interviews between 1982 and 1984 or later.[13,14] The validity of information obtained using this approach has been documented.[15,16]

FOLLOW-UP PROCEDURES

Follow-up data were collected between 1982 and 1984, and in 1986, 1987, and 1992.[13,14,17,18] Each follow-up examination included tracking a participant or his or her proxy to a current address; performing an in-depth interview; obtaining hospital and nursing home records, including pathological reports and electrocardiograms; and, for decedents, acquiring a death certificate. Incident CVD was based on documentation of an event that met prespecified study criteria and occurred between the participant's baseline examination and the last follow-up interview. The validity of study outcome data has been documented.[19]

Incident stroke was based on a death certificate report in which the underlying cause of death was recorded with an *International Classification of Diseases, Ninth Revision (ICD-9)*, code of 430 to 438 or one or more hospital and/or nursing home stays in which the participant had a discharge diagnosis with the codes previously mentioned. Incident CHD and CVD were defined in the same manner using *ICD-9* codes 410 to 414 and 390 to 459, respectively. Cause-specific mortality was identified by underlying cause of death using the previously mentioned *ICD-9* codes for stroke, CHD, and CVD. The date of record for incident events was identified by the date of the first hospital admission with an established study event or the date of death from a study event in the absence of hospital or nursing home documentation.

STATISTICAL ANALYSIS

Dietary total and water-soluble fiber intakes were calorie adjusted using the nutrient density method and modeled as categorical (quartile groups) variables in primary analyses and modeled continuously in additional analyses. Relative risk (RR) estimates were similar for both indexes. Total fiber–calorie and soluble fiber–calorie ratios were expressed as grams per 1735 kcal, the average calorie intake in the study population. The distribution of each baseline characteristic was calculated by quartile of total fiber–calorie and soluble fiber–calorie ratios (mean or percentage of study participants). The statistical significance of differences was examined by analysis of variance (for continuous variables) and by the χ^2 test (for categorical variables). Trend tests were conducted using orthogonal coefficients. The cumulative incidence of CVD by quartile of dietary fiber–calorie ratio was calculated using the Kaplan-Meier method,[20] and differences in cumulative rates were examined by the log-rank test for trend.[21] The adjusted relationship between dietary intake of total and soluble fiber and risk of CVD was modeled using the nutrient density method and Cox proportional hazards regression analysis.[22] Cox proportional hazards regression models were stratified by birth cohort using 10-year intervals to control for calendar period and cohort effects.[23] Age was used as the time scale in all time-to-event analyses.[23] Methods to estimate variance that take into account sample clustering and stratification of the NHANES I sample were used in the Cox proportional hazards regression models.[23] Because few participants remained and the all-cause mortality was disproportionately high after the age of 85 years, all analyses were truncated at this age.

RESULTS

In this cohort, the median total dietary fiber intake per 1735 kcal was 11.2 g and the median soluble dietary fiber intake per 1735 kcal was 2.4 g. The median intake in the highest quartile of total dietary fiber–calorie ratio was 20.7 g/d, whereas in the lowest quartile, the median intake was 5.9 g/d. For dietary intake of soluble fibers, the corresponding values were 5.9 and 0.9 g/d. Compared with those with a lower intake, participants with a higher total dietary fiber intake tended to be older, female, and white (**Table 1**). After age adjustment, participants who reported a higher intake of total dietary fiber had, on average, lower systolic and diastolic blood pressure readings than those consuming less dietary fiber; however, there was not a significant difference in the proportions with hypertension. Diabetes mellitus was

Table 1. Age-Adjusted Baseline Characteristics of 9776 NHEFS Participants by Quartile of Total Dietary Fiber*

Variable	Quartile of Total Dietary Fiber–Calorie (Energy) Ratio, g/1735 kcal <7.7	7.7-11.0	11.1-15.9	>15.9	*P* Value for Linear Trend
Age, y	47.3 ± 15.2	48.1 ± 15.5	49.8 ± 24.2	51.6 ± 15.7	<.001
Male sex†	43.8	41.4	35.8	32.2	<.001
White race†	77.9	84.0	87.6	85.5	<.001
BP, mm Hg					
Systolic	135.4 ± 42.1	134.2 ± 42.0	133.6 ± 41.9	134.4 ± 42.0	.05
Diastolic	83.9 ± 25.3	83.2 ± 25.2	82.8 ± 25.2	82.9 ± 25.3	.002
Hypertension†‡	30.1	24.9	26.6	28.5	.42
Serum cholesterol, mg/dL	220.5 ± 91.7	221.1 ± 91.5	220.1 ± 91.4	219.6 ± 91.7	.36
Hypercholesterolemia†§	31.6	32.1	31.1	30.5	.30
Diabetes mellitus†	3.2	3.9	3.8	5.5	<.001
Body mass index, kg/m^2	25.9 ± 10.2	25.5 ± 10.2	25.6 ± 10.2	25.6 ± 10.2	.05
Low recreational physical activity†	47.5	45.5	46.1	45.6	.25
Less than a high school education†	51.6	46.1	43.3	46.5	<.001
Current cigarette smoking†‖	42.6	35.8	31.7	29.7	<.001
Daily alcohol drinking†	27.4	24.7	22.6	19.7	<.001
Dietary intake per 24 h					
Saturated fat, g	29.6 ± 31.6	28.2 ± 31.6	25.1 ± 31.6	20.2 ± 31.7	<.001
Total fiber, g	5.8 ± 19.4	10.0 ± 19.4	13.1 ± 19.4	22.2 ± 19.4	<.001
Calories, kcal	1794 ± 1607	1836 ± 1605	1713 ± 1605	1596 ± 1610	<.001
Total fiber–calorie ratio, g/1735 kcal	5.6 ± 10.1	9.4 ± 10.1	13.3 ± 10.1	23.9 ± 10.1	<.001

Abbreviations: BP, blood pressure; NHEFS, National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study.
SI conversion factor: To convert cholesterol to millimoles per liter, multiply by 0.0259.
*Data are given as mean ± SD unless otherwise indicated. There were 2444 participants per quartile.
†Data are given as percentage of participants.
‡A systolic BP of 160 mm Hg or greater and/or a diastolic BP of 95 mm Hg or greater and/or use of an antihypertensive medication.
§A serum cholesterol level of 240 mg/dL or greater.
‖Data available for 2629 men and 3902 women.

more frequent in participants reporting a higher total fiber intake compared with those with a lower intake. In addition, participants consuming higher levels of total fiber were less likely to be smokers or to drink alcohol regularly. They consumed less saturated fat and fewer total calories than their counterparts consuming less total dietary fiber. Trends were similar when participants were divided according to their intake of soluble fiber, with the exceptions of educational level and physical activity (**Table 2**). Compared with their counterparts consuming less soluble fiber, those consuming more soluble fiber were less likely to have completed high school and slightly less likely to perform recreational physical activity.

During 161 352 person-years of follow-up between 1971 and 1992, 928 stroke events (233 fatal), 1843 CHD events (668 fatal), 3762 CVD events (1198 fatal), and 2632 deaths from all causes were documented. The RRs and 95% confidence intervals (CIs) for incidence of and mortality from stroke and CVDs and all causes are presented in **Table 3** and **Table 4**. In age-, race-, and sex-adjusted analyses, the incidence of CHD and mortality from all causes seemed inversely related to intake of total dietary fiber; however, these relationships did not reach the customary level of statistical significance. After additional adjustment for educational level, systolic blood pressure, serum total cholesterol level, diabetes mellitus, physical activity, regular alcohol consumption, smoking status, body mass index, and saturated fat intake, incident CHD and incident CVD were significantly associated with intake of total dietary fiber. Participants who consumed more than 15.9 g of total dietary fiber per 1735 kcal (upper quartile) had a 12% lower risk of CHD and an 11% lower risk of CVD, when compared with those who consumed fewer than 7.7 g of total dietary fiber per 1735 kcal (lower quartile) (Table 3).

In corresponding analyses for quartiles of water-soluble fiber, the associations were statistically significant for more of the study outcomes (Table 4). In age-, race-, and sex-adjusted analyses, dietary intake of soluble fiber was significantly associated with the risk of CHD, the risk of CVD, and mortality from all causes. After additional adjustment for the same risk factors included in the multivariate model for total dietary fiber intake, dietary intake of soluble fiber was significantly associated with CHD incidence, CHD-related mortality, CVD incidence, CVD-related mortality, and mortality from all causes. Persons consuming more than 4.0 g of soluble fiber per 1735 kcal (upper quartile) had a 15% lower risk of CHD, a 24% lower mortality from CHD, a 10% lower risk of CVD, a 12% lower mortality from CVD, and an 11% lower mortality from all causes compared with those consuming fewer than 1.3 g of soluble fiber per 1735 kcal (lower quartile).

Multivariate RRs of CVD and total mortality associated with a 10-g change in total dietary fiber and in dietary fiber–calorie ratio, and a 5-g change in soluble fiber and soluble fiber–calorie ratio, are presented in **Table 5**. Estimates of RR were similar for absolute intake of total dietary fiber (standard method of adjustment for calorie intake) and total fiber–calorie ratio (nutrient density method of adjustment for calorie intake). A 10-g increase in total dietary fiber was associated with

Table 2. Age-Adjusted Baseline Characteristics of 9776 NHEFS Participants by Quartile of Soluble Dietary Fiber*

Variable	Quartile of Soluble Dietary Fiber–Calorie (Energy) Ratio, g/1735 kcal <1.3	1.3-2.3	2.4-4.0	>4.0	*P* Value for Linear Trend
Age, y	45.3 ± 14.8	47.8 ± 15.3	50.7 ± 15.6	53.2 ± 15.6	<.001
Male sex†	43.9	41.1	37.6	30.6	<.001
White race†	79.8	85.1	86.0	84.0	<.001
BP, mm Hg					
Systolic	135.0 ± 42.2	134.2 ± 42.0	133.0 ± 41.9	135.2 ± 42.2	.70
Diastolic	84.1 ± 25.4	83.1 ± 25.2	82.7 ± 25.2	83.0 ± 25.4	.001
Hypertension†‡	29.7	25.7	26.4	28.4	.44
Serum cholesterol, mg/dL	220.9 ± 92.2	220.2 ± 91.6	219.5 ± 91.6	220.6 ± 92.2	.69
Hypercholesterolemia†§	32.0	31.3	30.3	31.5	.53
Diabetes mellitus†	3.0	3.6	4.0	5.6	<.001
Body mass index, kg/m^2	25.8 ± 10.3	25.7 ± 10.2	25.3 ± 10.2	25.8 ± 10.3	.22
Low recreational physical activity†	46.0	45.8	46.2	46.9	.51
Less than a high school education†	49.7	46.1	44.8	46.9	.02
Current cigarette smoking†‖	43.2	35.4	32.4	28.6	<.001
Daily alcohol drinking†	28.1	25.3	22.7	18.4	<.001
Dietary intake per 24 h					
Saturated fat, g	28.1 ± 32.0	28.9 ± 31.7	25.7 ± 31.7	20.4 ± 32.0	<.001
Soluble fiber, g	0.8 ± 8.4	1.9 ± 8.4	3.1 ± 8.4	7.1 ± 8.4	<.001
Calories, kcal	1804 ± 1615	1845 ± 1603	1722 ± 1603	1567 ± 1614	<.001
Soluble fiber–calorie ratio, g/1735 kcal	0.8 ± 5.2	1.8 ± 5.2	3.1 ± 5.2	7.7 ± 5.2	<.001

*Data are given as mean ± SD unless otherwise indicated. There were 2444 participants per quartile. Abbreviations are explained in the first footnote to Table 1, and the SI conversion factor is given in the second footnote to Table 1.
†Data are given as percentage of participants.
‡A systolic BP of 160 mm Hg or greater and/or a diastolic BP of 95 mm Hg or greater and/or use of an antihypertensive medication.
§A serum cholesterol level of 240 mg/dL or greater.
‖Data available for 2629 men and 3902 women.

a 7% lower incidence of CHD and CVD. A 5-g increase in absolute intake of soluble fiber was associated with a 6% lower incidence of CHD and a 5% lower incidence of CVD. When modeled using the nutrient density method, a 5-g increase in soluble fiber per 1735 kcal was associated with an 8% lower incidence of CHD, a 9% lower mortality from CHD, and a 6% lower incidence of CVD.

Similar trends were observed when dietary fiber was analyzed by food source—fruits and vegetables or cereals and grains. This finding was consistent for total and soluble dietary fiber. For example, consumption of at least 4.5 g of cereal and grain fiber per 1735 kcal was associated with a 20% lower risk of CHD (RR, 0.80; 95% CI, 0.63-1.01; *P*=.06 for trend) and an 11% lower risk of death from CHD (RR, 0.89; 95% CI, 0.76-1.02; *P*=.10 for trend), with borderline significance.

COMMENT

This study documents an independent inverse association between intake of total and water-soluble dietary fiber and risk of subsequent CHD and CVD in a representative sample of the US general population. These findings have important clinical and public health implications. In 1998, an estimated 459841 US residents died of CHD.[24] Our findings suggest that increasing dietary fiber intake, particularly water-soluble dietary fiber intake, may decrease the risk of CHD events, CVD events, and mortality from all causes.

Our results are consistent with findings from other large prospective studies of dietary total and water-soluble fiber intake and CVD. Pietinen et al[2] examined the risk of CHD events in 21930 Finnish male smokers between the ages of 50 and 69 years who participated in the α-Tocopherol, β-Carotene Cancer Prevention Study. For those in the highest quintile of total dietary fiber intake, the RR of CHD was 0.84 (95% CI, 0.71-1.01; *P*=.03 for trend), after adjustment for established CVD risk factors. The corresponding RR for water-soluble dietary fiber was 0.79 (95% CI, 0.66-0.94; *P*=.004 for trend). More recently, Wolk et al[3] found an inverse relationship between intake of dietary fiber from cereal sources and CHD in a cohort of 68782 female nurses. However, the results were not statistically significant for intake of water-soluble fiber after adjustment for established CVD risk factors like body mass index, regular physical activity, hypertension, and saturated fat intake. Each 5-g increase in water-soluble fiber was associated with an RR of CHD of 0.88 (95% CI, 0.77-1.01). Kushi,[1] Rimm,[4] and Liu[5] and colleagues also failed to demonstrate a significant relationship between water-soluble fiber and risk of CHD after adjustment for established CVD risk factors. Limitations in statistical power may have been responsible for this. The study by Pietinen et al included 1399 events and 581 deaths, while the study by Wolk et al included only 429 events and 162 deaths. In addition, these studies were conducted in populations that may have different food habits and other health behaviors than those pertaining to a general population. For example, the median calorie-adjusted total fiber intake in the lowest quintile in the Health Professionals' Follow-up Study[4] was 12.4 g, whereas in our study, the median calorie-adjusted total fiber intake in the lowest quartile was 5.9 g. Our study was conducted in a nationally representative sample of

Table 3. Data for Stroke, CHD, CVD, and Total Mortality According to Quartile of Total Dietary Fiber*

Variable	Quartile of Total Dietary Fiber–Calorie (Energy) Ratio, g/1735 kcal <7.7†	7.7-11.0	11.1-15.9	>15.9	*P* Value for Trend
Stroke					
Incidence					
No. of events	221	213	226	268	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.93 (0.77-1.11)	0.86 (0.69-1.06)	0.92 (0.79-1.07)	.19
Multivariate‡	1.00	0.98 (0.81-1.19)	0.89 (0.72-1.11)	0.95 (0.78-1.16)	.44
Mortality					
No. of events	58	50	58	67	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.87 (0.54-1.41)	0.84 (0.59-1.19)	0.86 (0.61-1.20)	.38
Multivariate‡	1.00	0.99 (0.58-1.71)	1.02 (0.69-1.50)	0.99 (0.64-1.53)	.99
CHD					
Incidence					
No. of events	438	452	464	489	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.97 (0.83-1.12)	0.90 (0.80-1.03)	0.90 (0.77-1.04)	.08
Multivariate‡	1.00	1.01 (0.87-1.17)	0.91 (0.80-1.02)	0.88 (0.74-1.04)	.05
Mortality					
No. of events	162	154	160	192	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.88 (0.68-1.13)	0.82 (0.65-1.04)	0.93 (0.74-1.16)	.42
Multivariate‡	1.00	0.87 (0.68-1.12)	0.79 (0.63-0.99)	0.85 (0.65-1.10)	.15
CVD					
Incidence					
No. of events	919	928	930	985	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.98 (0.88-1.09)	0.91 (0.83-1.01)	0.91 (0.82-1.01)	.28
Multivariate‡	1.00	1.02 (0.91-1.13)	0.93 (0.84-1.03)	0.89 (0.80-0.99)	.01
Mortality					
No. of events	293	281	280	344	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.92 (0.76-1.12)	0.81 (0.70-0.94)	0.92 (0.78-1.10)	.15
Multivariate‡	1.00	0.95 (0.78-1.15)	0.84 (0.72-0.97)	0.93 (0.77-1.12)	.20
Mortality From All Causes					
No. of events	647	638	607	740	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.95 (0.83-1.10)	0.82 (0.73-0.92)	0.94 (0.82-1.07)	.09
Multivariate‡	1.00	0.97 (0.84-1.12)	0.85 (0.76-0.96)	0.96 (0.84-1.11)	.27

Abbreviations: CHD, coronary heart disease; CI, confidence interval; CVD, cardiovascular disease; NA, data not applicable; RR, relative risk.
*There were 2444 participants per quartile. The number of person-years per quartile was as follows: less than 7.7 g, 40 733; 7.7 to 11.0 g, 40 860; 11.1 to 15.9 g, 40 556; and greater than 15.9 g, 39 203.
†Reference.
‡Stratified by birth cohort and adjusted for age, sex, race, educational level, systolic blood pressure, serum total cholesterol level, diabetes mellitus, physical activity, regular alcohol consumption, smoking status, body mass index, and saturated fat intake; n = 9248.

the US noninstitutionalized population. Consequently, our findings can be generalized at a national level.

In our study, persons in the upper quartiles of dietary fiber–calorie ratio were more likely to have diabetes mellitus. This may be because persons with diabetes mellitus are likely to change their diet to control their serum glucose levels, or at least be advised to do so. Such change may account for higher percentages of persons with diabetes mellitus in the upper quartiles of the dietary fiber-calorie ratio.

Dietary fiber has been shown to delay the absorption of carbohydrates after a meal and thereby decrease the insulinemic response to dietary carbohydrates.[24] Experimental studies[25] have also shown that higher levels of insulin may promote dyslipidemia, hypertension, abnormalities in blood clotting factors, and atherosclerosis. In addition, water-soluble dietary fiber has been shown to decrease total and low-density lipoprotein cholesterol levels while not affecting levels of high-density lipoprotein cholesterol.[6] While the cholesterol-reducing effects of dietary fiber are usually thought to be modest, they may play a role in the inverse association between dietary intake of fiber and CHD risk.[7] Moreover, recent studies[8,26,27] have suggested inverse associations between dietary fiber and other CVD risk factors, such as blood pressure, waist-hip ratio, fasting insulin level, 2-hour postglucose insulin level, levels of triglycerides, and levels of fibrinogen. We adjusted estimates of risk for blood pressure, body mass index, and serum cholesterol level to determine if dietary fiber intake is associated with risk

Table 4. Data for Stroke, CHD, CVD, and Total Mortality According to Quartile of Soluble Dietary Fiber*

Variable	Quartile of Soluble Dietary Fiber–Calorie (Energy) Ratio, g/1735 kcal: <1.3†	1.3-2.3	2.4-4.0	>4.0	*P* Value for Trend
Stroke					
Incidence					
No. of events	204	205	224	295	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.86 (0.73-1.02)	0.78 (0.64-0.95)	0.89 (0.76-1.05)	.10
Multivariate‡	1.00	0.84 (0.72-0.99)	0.80 (0.66-0.97)	0.88 (0.73-1.06)	.14
Mortality					
No. of events	57	43	41	92	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.65 (0.41-1.04)	0.49 (0.34-0.71)	0.93 (0.69-1.26)	.32
Multivariate‡	1.00	0.64 (0.40-1.01)	0.55 (0.37-0.83)	0.93 (0.63-1.37)	.55
CHD					
Incidence					
No. of events	398	460	467	518	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	1.00 (0.90-1.11)	0.86 (0.76-0.97)	0.89 (0.78-1.01)	.02
Multivariate‡	1.00	1.04 (0.92-1.17)	0.88 (0.78-1.00)	0.85 (0.74-0.98)	.004
Mortality					
No. of events	144	160	172	192	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.91 (0.73-1.14)	0.81 (0.62-1.04)	0.84 (0.66-1.07)	.09
Multivariate‡	1.00	0.95 (0.76-1.20)	0.80 (0.62-1.05)	0.76 (0.60-0.97)	.01
CVD					
Incidence					
No. of events	847	923	948	1044	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.99 (0.92-1.08)	0.91 (0.82-1.01)	0.93 (0.84-1.03)	.05
Multivariate‡	1.00	1.02 (0.94-1.10)	0.94 (0.84-1.06)	0.90 (0.82-0.99)	.01
Mortality					
No. of events	262	274	280	382	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.88 (0.74-1.06)	0.74 (0.61-0.88)	0.92 (0.78-1.07)	.06
Multivariate‡	1.00	0.91 (0.75-1.10)	0.76 (0.62-0.93)	0.88 (0.75-1.04)	.03
Mortality From All Causes					
No. of events	588	622	649	773	NA
RR (95% CI)					
Age-, race-, and sex-adjusted	1.00	0.92 (0.82-1.03)	0.80 (0.70-0.91)	0.89 (0.79-0.99)	.01
Multivariate‡	1.00	0.94 (0.83-1.06)	0.82 (0.72-0.95)	0.89 (0.79-1.00)	.02

*There were 2444 participants per quartile. The number of person-years per quartile was as follows: less than 1.3 g, 41 719; 1.3 to 2.3 g, 41 033; 2.4 to 4.0 g, 40 137; and greater than 4.0 g, 38 462. Abbreviations are explained in the first footnote to Table 3.

†Reference.

‡Stratified by birth cohort and adjusted for age, sex, race, educational level, systolic blood pressure, serum total cholesterol level, diabetes mellitus, physical activity, regular alcohol consumption, smoking status, body mass index, and saturated fat intake; n = 9248.

of CVD independent of these factors. As with all observational epidemiologic studies, imperfect measurement of factors used in adjustment may affect risk estimates.

It has been suggested that the apparent protective effect of fiber on CVD risk may be because of other healthy habits, such as regular exercise, not smoking cigarettes, and a low dietary intake of cholesterol and saturated fat in persons who consume greater amounts of dietary fiber.[28] The estimates of risk we present herein were adjusted for all of those potential confounders of the relationship between dietary fiber and CVD. Moreover, adjustment for these factors strengthened the estimates of the association. For instance, the RR associated with consuming greater than 4.0 g of soluble fiber per 1735 kcal compared with fewer than 1.3 g of soluble fiber per 1735 kcal was 0.89 (95% CI, 0.78-1.01) for risk of CHD after adjustment for age, race, and sex. With further adjustment for all of the previously mentioned risk factors, the RR changed minimally to 0.85 (95% CI, 0.74-0.98).

Our study has several important strengths. First, the findings can be generalized on a national level because the NHANES I Epidemiologic Follow-up Study cohort is a random sample of the adult noninstitutionalized population. In addition, temporal relationships can be established with confidence because dietary intakes of total and water-soluble fiber were measured at baseline, and subsequent CVD and total mortality were assessed over an average of 19 years. The fact that follow-up experience was available for more than 96% of the study participants further enhances the validity of our findings.

One limitation of this study is that dietary fiber was estimated using a single 24-hour dietary recall. This may

Table 5. Multivariate Data for Stroke, CHD, CVD, and Total Mortality Associated With a 10-g Change in Total Dietary Fiber and a 5-g Change in Soluble Dietary Fiber

Variable	Absolute Dietary Intake*	*P* Value	Fiber–Calorie (Energy) Ratio*†	*P* Value
		Total Fiber		
Stroke				
Incidence	0.96 (0.89-1.04)	.29	0.94 (0.87-1.02)	.12
Mortality	1.07 (0.93-1.23)	.34	1.02 (0.85-1.24)	.80
CHD				
Incidence	0.93 (0.88-0.98)	.01	0.92 (0.86-0.98)	.01
Mortality	0.92 (0.84-1.01)	.09	0.91 (0.83-1.00)	.06
CVD				
Incidence	0.93 (0.90-0.97)	<.001	0.93 (0.89-0.97)	<.001
Mortality	0.97 (0.93-1.02)	.22	0.96 (0.90-1.03)	.29
Mortality from all causes	0.98 (0.94-1.03)	.42	0.98 (0.92-1.03)	.39
		Soluble Fiber		
Stroke				
Incidence	0.96 (0.89-1.03)	.27	0.95 (0.88-1.03)	.18
Mortality	1.07 (0.93-1.22)	.33	1.03 (0.83-1.28)	.78
CHD				
Incidence	0.94 (0.89-0.99)	.02	0.92 (0.87-0.97)	.004
Mortality	0.94 (0.86-1.03)	.20	0.91 (0.83-0.99)	.03
CVD				
Incidence	0.95 (0.92-0.98)	.003	0.94 (0.90-0.99)	.01
Mortality	0.99 (0.95-1.04)	.73	0.98 (0.93-1.04)	.48
Mortality from all causes	0.99 (0.95-1.03)	.52	0.98 (0.93-1.03)	.34

Abbreviations: CHD, coronary heart disease; CVD, cardiovascular disease.

*Data are given as relative risk (95% confidence interval). These multivariate models are stratified by birth cohort and adjusted for age, sex, race, educational level, systolic blood pressure, serum total cholesterol level, diabetes mellitus, physical activity, regular alcohol consumption, smoking status, body mass index, and saturated fat and total calorie intakes; n = 9248.

†The ratio was 10 g/1735 kcal for total fiber and 5 g/1735 kcal for soluble fiber.

result in misclassification of usual dietary fiber intake at the individual level. In addition, dietary fiber intake was not collected during the follow-up. These measurement errors would tend to bias our RR estimates toward the null value in univariate models. A second limitation of this study is underreporting of dietary calorie intake by some NHANES I study participants.[29,30] Adjustment for calorie intake in our analyses may have reduced the potential impact of such underreporting.

In conclusion, our findings suggest that a high dietary fiber intake, particularly of water-soluble fiber, is strongly and independently associated with a lower risk of CHD and CVD and mortality from these and other causes in a representative sample of the US noninstitutionalized population. Cereal grains and legumes are excellent sources of water-soluble dietary fiber. Approximately one fourth of the fiber provided by cereal sources is water soluble. A half cup of cooked beans contains on average of 6 g of total fiber and 2 g of soluble fiber.[31] Our findings of a 12% lower risk of CHD and an 11% lower risk of CVD for persons consuming more than 15.9 g/1735 kcal (mean total dietary fiber intake, 22.0 g/24 h; SD, 17.6 g/24 h) support the existing American Heart Association[31] recommendations to increase dietary fiber intake from foods to approximately 25 to 30 g/d, aimed at reducing CHD and CVD in the US adult population.

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