Published in final edited form as:
Arch Intern Med. 2011 June 27; 171(12): 1061–1068. doi:10.1001/archinternmed.2011.18.

Dietary fiber intake and mortality in the NIH-AARP Diet and Health Study

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Abstract

Background—Dietary fiber has been hypothesized to lower risk of coronary heart disease, diabetes, and some cancers. However, little is known of the effect of dietary fiber on total death and cause-specific deaths.

Methods—We examined dietary fiber intake in relation to total mortality and death from specific causes in the NIH-AARP Diet and Health Study, a prospective cohort study. Diet was assessed using a food frequency questionnaire at baseline. Cause of death was identified using the National Death Index Plus. Cox proportional hazard models were used to estimate relative risks (RRs) and two-sided 95% confidence intervals (CI).

Results—During an average of 9 years of follow-up, we identified 20,126 deaths in men and 11,330 deaths in women. Dietary fiber intake was associated with significantly lowered risk of total death in both men and women (multivariate RR comparing the highest vs. the lowest quintile =0.78, 95% CI:0.73–0.82, p-trend, <0.001 in men; 0.78. 95% CI:0.73–0.85, p-trend, <0.001 in women). Dietary fiber intake also lowered risk of death from cardiovascular, infectious, and respiratory diseases by 24%–56% in men and 34%–59% in women. Inverse association between dietary fiber intake and cancer death was observed in men, but not in women. Dietary fiber from grains, but not from other sources, was significantly inversely related to total and cause-specific death in both men and women.

Conclusions—Dietary fiber may reduce the risk of death from cardiovascular, infectious and respiratory diseases. Making fiber-rich food choices more often may provide significant health benefits.

Dietary fiber is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine [1]. Dietary fiber has been hypothesized to lower risk of coronary heart disease, diabetes, some cancers, obesity, and premature death because it is known to 1) improve laxation by increasing bulk and reducing transit time of feces through the bowel; 2) increase excretion of bile acid, estrogen, and fecal procarcinogens and carcinogens by binding to them; 3) lower serum cholesterol; 4) slow glucose absorption and improve insulin

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sensitivity; 5) lower blood pressure; 6) promote weight loss; 7) inhibit lipid peroxidation; and 8) have anti-inflammatory properties [2–3].

A limited number of observational studies has examined the effect of dietary fiber on mortality and reported inconsistent results. The Scottish Heart Health study (n=11,629, total death=591) [4] found that dietary fiber intake was inversely related to total mortality in men, but not in women. The Zutphen study in the Netherlands [5], which followed 1,373 men for 40 years, found a 9% lowered risk of total death per 10 g/day of dietary fiber intake. Another study conducted in Israeli population [6] also observed a 43% lowered risk of total death in people consuming ≥25 g/day of dietary fiber compared to those with <25 g/day dietary fiber intake. On the other hand, the National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study [7] (n=9,776, total death=2,632) found no association between dietary fiber intake and total mortality. However, this study assessed dietary fiber intake using a single 24-hour dietary recall, unlikely to reflect usual dietary intake.

Studies of dietary fiber in relation to cause-specific death, except cardiovascular disease (CVD) death, are sparse. Furthermore, previous studies examining the association between dietary fiber and mortality were limited by small sample sizes, narrow ranges of dietary fiber intakes, and inadequate control for confounding leading to decreased power, intakes without the necessary ranges to observe associations and residual confounding.

Therefore, we investigated dietary fiber intake in relation to total and cause-specific mortality in a large prospective cohort of men and women, which has more than 30,000 deaths occurred during an average of 9 years of follow-up and a wide range of dietary intakes.

SUBJECTS AND METHODS

Study population

The National Institutes of Health (NIH)-AARP Diet and Health Study was initiated when 567,169 AARP members aged 50–71 years from six U.S. states (California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania) and two metropolitan areas (Atlanta, Georgia, and Detroit, Michigan) responded to a mailed questionnaire in 1995–96. Details of the NIH-AARP Study has been described previously [8]. Among participants who returned questionnaires with satisfactory dietary data, we excluded individuals who indicated that they were proxies for the intended respondent (n=1,265), who had any prevalent cancer except non-melanoma skin cancer (n=23,954), heart disease (n=68,664), stroke (n=6,434) or diabetes (n=30,881), or self-reported end stage renal disease at baseline (n=371). In addition, we excluded individuals who reported extreme intakes (beyond 2 times the interquartile ranges of Box-Cox log transformed intake) of total energy (n=1,609) and dietary fiber (n= 891). After exclusions, the analytic cohort consisted of 219,123 men and 168,999 women. The NIH-AARP Diet and Health study was approved by the Special Studies Institutional Review Board of the U.S. National Cancer Institute.

Diet and risk factor assessment

At baseline, dietary intakes were assessed with a self-administered 124 item food frequency questionnaire (FFQ), which was an early version of the Diet History Questionnaire developed at the National Cancer Institute [9]. Participants were asked to report their usual frequency of intake and portion size over the past 12 months, using 10 predefined frequency categories ranging from ‘never’ to ‘6+ times per day’ for beverages and from ‘never’ to ‘2+ times per day’ for solid foods; and 3 categories of portion size. The food items, portion sizes and nutrient database were constructed using the U.S. Department of Agriculture’s 1994–96

Continuing Survey of Food Intakes by Individuals [10]. The nutrient database for dietary fiber was informed by the Association of Official Analytical Chemist (AOAC) method [11].

The FFQ used in the study was calibrated using two non-consecutive 24-hour dietary recalls in 1,953 NIH-AARP study participants [12]. The energy-adjusted correlation coefficients of dietary fiber intake between a FFQ and 24-hr recalls were 0.72 in men and 0.66 in women.

We also collected demographic, anthropometric, lifestyle information including smoking, physical activity, family history of cancers, and menopausal hormone therapy use in women, and some medical conditions at baseline.

Mortality Ascertainment

We ascertained vital status through a periodic linkage of the cohort to the Social Security Administration Death Master File and follow-up searches of the National Death Index Plus for participants who matched to the Social Security Administration Death Master File, cancer registry linkage, questionnaire responses, and responses to other mailings. We used *International Classification of Diseases, 9th and 10th revision* to define death due to cardiovascular diseases (CVD, I00-I78), cancer (C00-C97), infectious diseases (e.g. tuberculosis, septicemia, and other infectious and parasitic diseases, A00-B99 excluding B20-B24), respiratory diseases (e.g. pneumonia, influenza, chronic obstructive pulmonary diseases and allied conditions, J10-J18, J40-J47), accidents (e.g. accident, suicide, and homicide, V01-X59), and other causes (all other causes except mentioned above).

Statistical analysis

We used the Cox proportional hazards model[13] to estimate relative risks (RRs) and two-sided 95% confidence intervals (CI), using the SAS PROC PHREG procedure (version 9.1; SAS Institute, Inc, Cary, NC). Person-years of follow-up time were calculated from the date of the baseline questionnaire until the date of death or end of follow-up (December, 31, 2005), whichever occurred first. We evaluated the proportional hazards assumption and confirmed it by modeling interaction terms comprising the cross-product of time and dietary fiber intake.

Although there was no statistically significant interaction by sex (p=0.17), we performed sex-specific analysis and report the results by sex. Intakes of dietary fiber and fiber from food sources were adjusted for total energy intake using the residual method [14] and were categorized into quintiles. We estimated the RRs for quintiles of fiber intake as well as continuous intake. To test linear trends across quintiles of fiber intake, we created a continuous variable based on the median value in each quintile and regressed risk of death on this variable.

We presented an age-adjusted model and two multivariate models. The multivariate model I adjusted for age, smoking status, smoking dose, and time since quitting smoking because smoking was a strong confounder. In multivariate model II, we additionally adjusted for race/ethnicity, education, marital status, self-rated health status, body mass index (BMI), physical activity, menopausal hormone therapy use in women, and intakes of alcohol, red meat, fruits, vegetables, and total energy. In addition, we further adjusted for aspirin use, high cholesterol level, and high blood pressure and found that the results did not change. For missing data in each covariate, we created an indicator variable reflecting missing data. Generally missingness was <5%. We tested whether the association between dietary fiber and mortality was modified by smoking and body mass index. The test for interaction was performed using the likelihood ratio test entering a cross-product term of dietary fiber intake and body mass index both as continuous variables and smoking as an ordinal variable. In analyses of fiber from food sources, fiber intake from grains, fruits, vegetables, and beans were mutually adjusted.

Also, we carried out measurement error corrections using a regression calibration method [15–16] and a SAS macro [17] for an age-adjusted model and a parsimonious multivariate model that adjusted for age, smoking, and total energy intake. The relative risks for dietary fiber intake were corrected for measurement error by regressing intake from the reference dietary assessment method, two non-consecutive 24-hour recalls, on intake from the FFQ.

RESULTS

During an average of 9 years of follow-up, we identified 20,126 deaths in men and 11,330 deaths in women. There were 5,248 CVD deaths and 8,244 cancer deaths in men and 2,417 CVD deaths and 4,927 cancer deaths in women. Age-adjusted total, CVD, and cancer mortality rate per 100, 000 person-years was 991, 258, and 406, respectively, in men and 716, 153, and 311, respectively, in women. Energy adjusted dietary fiber intake ranged from 13 g/day (10^{th} percentile) to 29 g/day (90^{th} percentile) in men and from 11 g/day to 26 g/day in women. The ranges (10^{th}–90^{th} percentile) of energy adjusted fiber intake from grains, fruits, vegetables, and beans were 3.3–11.1, 0.9–8.0, 3.1–10.6, and 0.6–4.8 g/day, respectively, in men and 2.5–8.8, 1.0–8.1, 2.9–10.3, and 0.3–3.4 g/day, respectively, in women. Compared to individuals in the lowest quintile of dietary fiber intake, people in the highest quintile were more likely to have higher education, to self-rated their health as being very good/excellent, to have lower BMI, to be physically active, and to use menopausal hormone therapy in women, but were less likely to smoke, to drink alcohol, and to consume red meat (Table 1).

We found that dietary fiber intake was significantly inversely associated with risk of total death in both men and women (Table 2). Comparing the lowest quintile of dietary fiber intake, both men and women in the highest quintile had a 22% lower risk of total death (multivariate $RR_{Q5\ vs\ Q1}$=0.78, 95% CI: 0.73–0.82 in men; 0.78. 95% CI:0.73–0.85 in women). For an increment of 10 g/day of dietary fiber intake, the multivariate RR for total death was 0.88 (95% CI: 0.86–0.91) in men and 0.85 (95% CI: 0.82–0.89) in women. We also performed the propensity score analysis to better control for confounding and found that the results did not materially change. Comparing the highest quintile of dietary fiber intake to the lowest, RR for total death was 0.82 (95% CI:0.80–0.84) in men and 0.84 (95% CI: 0.81–0.87) in women. Because smoking was a strong confounder in our analysis, we performed analyses stratified by smoking status. The association between dietary fiber intake and total death remained significantly in never smokers in both men (multivariate $RR_{Q5\ vs\ Q1}$=0.81, 95% CI: 0.71–0.93, p-trend=<0.001) and women (multivariate $RR_{Q5\ vs\ Q1}$=0.83, 95% CI:0.72–0.97, p-trend=0.05). Dietary fiber intake was also significantly inversely related to total death in former and current smokers in both men and women. A significant association with dietary fiber intake was also observed across categories of BMI. Furthermore, we examined the association stratified by age at baseline (<60 and ≥60 years old), self-rated health condition (excellent/good and fair/poor), and menopausal hormone therapy use in women (never and ever) and observed a consistently inverse association between dietary fiber intake and total death across all categories examined (data not shown).

Correction for measurement error in the assessments of dietary fiber intake strengthened the association with total mortality. For an increment of 10 g/day of dietary fiber intake, the RRs of total death, adjusting for age, smoking, and total energy intake, was 0.86 (95% CI: 0.84–0.88) in men and 0.83 (95% CI:0.80–0.86) in women before measurement error correction.

After correcting for measurement error, the RR were 0.76 (95% CI:0.72–0.80) in men and 0.71 (95% CI:0.66–0.76) in women.

Dietary fiber intake was also inversely related to risk of death from CVD, cancer, and infectious and respiratory diseases in men (Table 3). Comparing the highest to the lowest quintile of dietary fiber intake, men had a 24% – 56% lower risk of death from CVD, cancer, and infectious and respiratory diseases. Comparable findings in women were a 34%–59% lower risk of death from CVD and infectious and respiratory diseases and no association with cancer death (Table 4). For every 10 g/day increase in dietary fiber intake, the multivariate RRs for death from CVD, cancer, and infectious and respiratory diseases were 0.88 (95% CI: 0.86–0.91), 0.92 (95% CI: 0.88–0.96), 0.66 (95% CI: 0.52–0.84) and 0.82 (95% CI: 0.74–0.93), respectively, in men and 0.76 (95% CI: 0.69–0.84), 0.97 (95% CI: 0.91–1.04), 0.61 (95% CI: 0.44–0.85) and 0.66 (95% CI: 0.56–0.78), respectively, in women.

We further adjusted for aspirin use, high blood pressure, and cholesterolemia and found no appreciable differences. In addition, we analyzed the data by excluding death occurring the first 2 to 4 years of follow-up and found no change in results. When we restricted analyses to never smokers, the multivariate $RR_{Q5\ vs\ Q1}$ of death from CVD, cancer, and infectious and respiratory diseases in men were 0.95 (95% CI: 0.74–1.21, p-trend=0.81, 1134 death), 0.82 (95% CI: 0.65–1.03, p-trend= 0.009, 1405 death), 0.22 (95% CI: 0.08–0.61, p-trend= 0.002, 70 death), and 0.60 (95% CI: 0.25–1.44, p-trend=0.20, 90 death), respectively. In never smoked women, the multivariate $RR_{Q5\ vs\ Q1}$ were 0.69 (95% CI: 0.50–0.95, p-trend= 0.02, 729 death) for CVD death, 1.14 (95% CI: 0.90–1.44, p-trend=0.11, 1342 death) for cancer death, 0.28 (95% CI: 0.10–0.80, p-trend=0.02, 70 death) for infectious disease death, and 0.50 (95% CI: 0.22–1.14, p-trend=0.07, 103 death) for respiratory disease death.

Fiber intakes from food sources such as grains, fruits, vegetables and beans were also examined (Figure 1). We found that dietary fiber from grains was significantly inversely related to risk of total, CVD, cancer, and respiratory disease death in both men and women. Comparing the highest to the lowest intake of fiber from grains, men had a 22% lower risk of total death (multivariate RR=0.77, 95% CI:0.73–0.81) and women had a 19% lower risk of total death (multivariate RR=0.81, 95% CI:0.76–0.86). Fiber from vegetables and beans was also weakly associated with lower risk of total death in both men and women. However, fiber from fruits was not related to total and cause-specific death in men and women.

DISCUSSION

In this large prospective cohort study, we found that dietary fiber intake was significantly inversely associated with risk of total death and death from CVD, infectious diseases and respiratory diseases in both men and women. Dietary fiber intake was also related to a lower risk of death from cancer in men, but not in women. Among specific sources of dietary fiber, fiber from grains showed the most consistent inverse association with risk of total and cause-specific death.

Three of four previous studies that examined dietary fiber intake in relation to total mortality reported 9%–43% lowered risk of total death among those with higher consumption of dietary fiber in various populations [4–6]. Consistent with most of these studies, our study found a 22% lower risk of total death comparing the highest to the lowest quintile of intake in both men and women. Furthermore, the association was not modified by smoking status or BMI. The findings remained robust when we corrected for dietary intake measurement error using calibration study data, in fact, the association were even stronger with measurement error correction.

Dietary fiber intake in relation to CVD death has been studied in several studies [5, 18–21], consistently showing protection for CVD death, consistent with our study. A pooled analysis of 10 prospective cohort studies estimated that risk of CVD death decreased by about 19% (multivariate RR=0.81, 95% CI:0.73–0.91) per 10 g/day increment of dietary fiber intake[22]. This pooled study also found that fiber intake from grains and fruits were each associated with a lower risk of CVD death. Our findings were consistent for fiber intake from grains, but not from fruits. Several plausible mechanisms such as improving serum lipid profiles[23], postprandial absorption and insulin resistance[24], and lowering blood pressure[25] have been suggested to underlie the beneficial effects of dietary fiber on CVD.

Studies of dietary fiber intake in relation to cause-specific death other than CVD are limited. The role of dietary fiber in cancer etiology has long been debated. Despite plausible physiological mechanisms, the association between dietary fiber and cancer has been inconsistent. The consensus report from the World Cancer Research Fund and American Institute for Cancer Research concluded that dietary fiber probably lower incidence of colorectal and esophageal cancer [26], but little is known about dietary fiber intake in relation to cancer death. In our study, we observed an inverse association between dietary fiber intake and cancer death in men, but not in women. The observed gender difference may, in part, be due to the differences in leading organ sites for cancer death between men and women. Men have higher mortality rates of cancers of the head and neck, esophagus, liver, urinary bladder, and kidney compared to women. Considering data indicating that the risks of these cancers are influenced by several dietary factors including grains, fruits, and vegetables [27], our findings of protective effect of dietary fiber on total cancer death may have been due, in part, by lowering mortality of these specific cancers in men. Nonetheless, we can not rule out the possibility that our findings of different associations between dietary fiber intake and cancer death between men and women is due to chance. Future research might elucidate this finding.

Interestingly our study found that dietary fiber intake, especially from grains was inversely associated with risk of death from infectious and respiratory diseases. Inflammation, a predominant pathphysiologic response in many infectious and respiratory diseases, has been suggested to contribute the progression of these diseases [28]. Studies have shown that dietary fiber has anti-inflammatory properties: dietary fiber intake was associated with lower levels of inflammation markers such as C-reactive protein, interlukin-6, and TNF-α-R2, which play roles in chronic inflammatory conditions [29–32]. The anti-inflammatory properties of dietary fiber could explain, in part, significant inverse associations of dietary fiber with infectious and respiratory diseases as well as with CVD death. The Iowa Women's Health Study [33] found that women consuming a large amount of whole grain, rich sources of fiber, mineral, and other phytochemicals, had a 34% lower risk of death from non cardiovascular, non cancer inflammatory diseases ($RR_{Q5\ vs.\ Q1}$=0.66, 95% CI: 0.54–0.81, p-trend= 0.008) and a 40% lower risk of death from respiratory system diseases ($RR_{Q5\ vs.\ Q1}$=0.60, 95% CI: 0.46–0.80, p-trend=0.006). Few other studies have also suggested that dietary fiber intake lowers risk of inflammatory diseases such as duodenal ulcer and diverticular disease [34–35].

Our study has several strengths. First, this is a large prospective cohort study in which diet was measured at baseline, thus decreasing the likelihood of recall bias. In addition, our study has wide ranges of dietary fiber intake and a large number of deaths providing good statistical power and sample size to examine the associations in never smokers and relations to specific causes of death such as infectious and respiratory diseases. Our findings of beneficial effect of dietary fiber for infectious and respiratory diseases is interesting, but warrant further investigation. Second, we excluded people reporting chronic diseases such as heart disease, stroke, diabetes, and end-stage renal disease at baseline, who presumably are already at high risk of death and may have been prone to biased reporting of dietary fiber intake given the perception that dietary fiber is a healthy dietary constituents, thus attenuating associations. Lastly, we extensively controlled for smoking and many other risk factors of mortality. In addition, we performed analyses in never smokers only to minimize residual confounding by smoking, the strongest confounder, and still observed consistently significant inverse associations.

Several potential limitations also need to be considered. We can not rule out the possibility that dietary fiber intake is a marker of healthy diet that is high in grains, fruits, and vegetables, food that are rich in vitamins, minerals, antioxidants, and phytochemicals or that dietary fiber intake is a marker of a healthy lifestyle. People who consumed high amount of dietary fiber may engage in other healthy behaviors that were incompletely assessed in the study. Thus, our finding may be in part due to residual confounding by healthy lifestyle. However, we found significant inverse associations even after controlling for all these factors in multivariate models. In addition, inverse associations between dietary fiber intake and total and cause-specific deaths were observed in never smokers and in people with a BMI <25. Measurement error is always an inherent limitation in self-reported dietary assessment. Nevertheless, our measurement error correction analyses strengthened our associations. This suggests that measurement errors in dietary fiber intake may have attenuated the true relative risks, but the measurement errors were not substantial, thus we were able to detect an association in the study. We, however, recognize that the reference method, 24-hr recalls, used in our measurement error correction may under or over estimate true intake. Thus, it's possible that substantial changes in risk estimates could occur if an objective marker of intake, which may be close to the true intake, is used in measurement error correction.

In conclusion, our study shows that dietary fiber may reduce the risk of premature death from all cause, especially death from CVD and infectious and respiratory diseases. The current Dietary Guidelines for Americans recommend choosing fiber-rich fruits, vegetables, and whole grains often and consuming 14g/1,000 calories of dietary fiber. A diet rich in dietary fiber from whole plant foods may provide significant health benefits.

Acknowledgments

We are indebted to the participants in the NIH-AARP Diet and Health Study for their outstanding cooperation. We also thank Sigurd Hermansen and Kerry Grace Morrissey from Westat for study outcomes ascertainment and management and Leslie Carroll at Information Management Services for data support and analysis.

The study was supported by the Intramural Research Program of the National Cancer Institute, National Institutes of Health.

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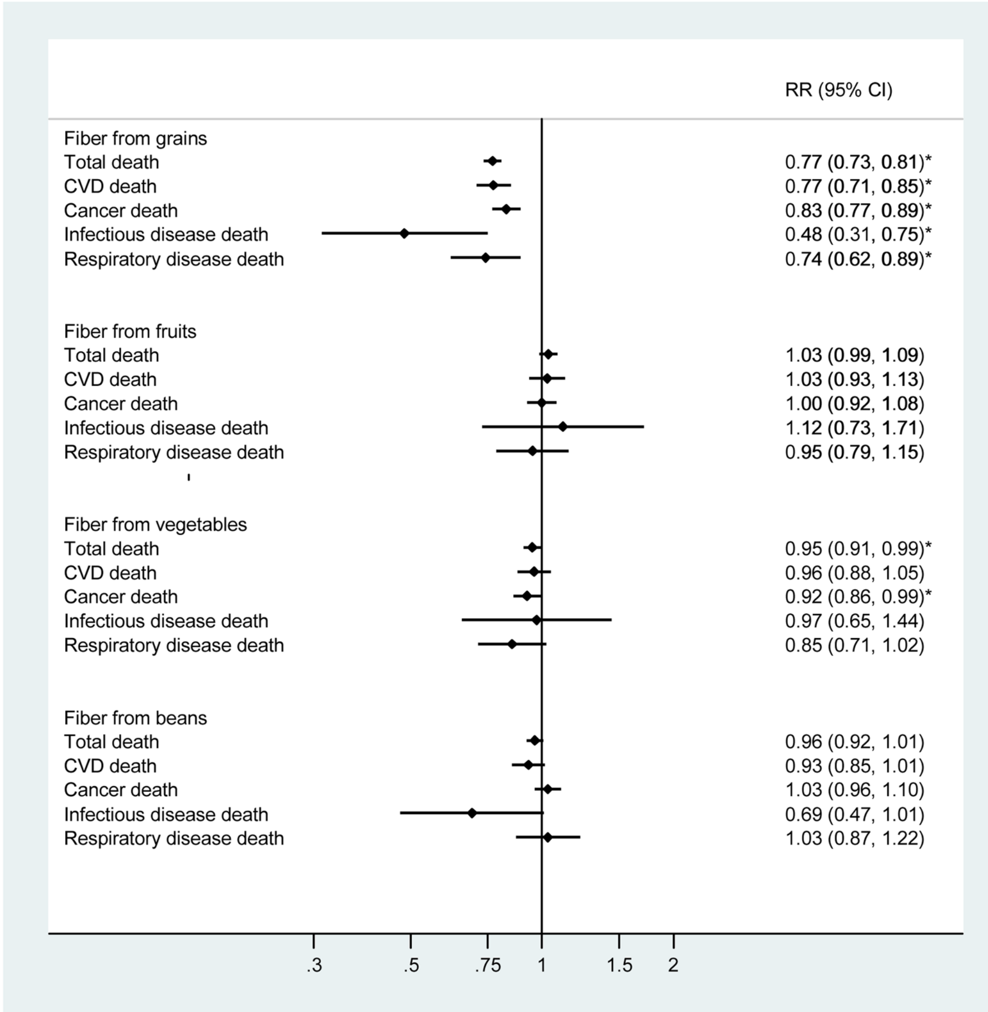
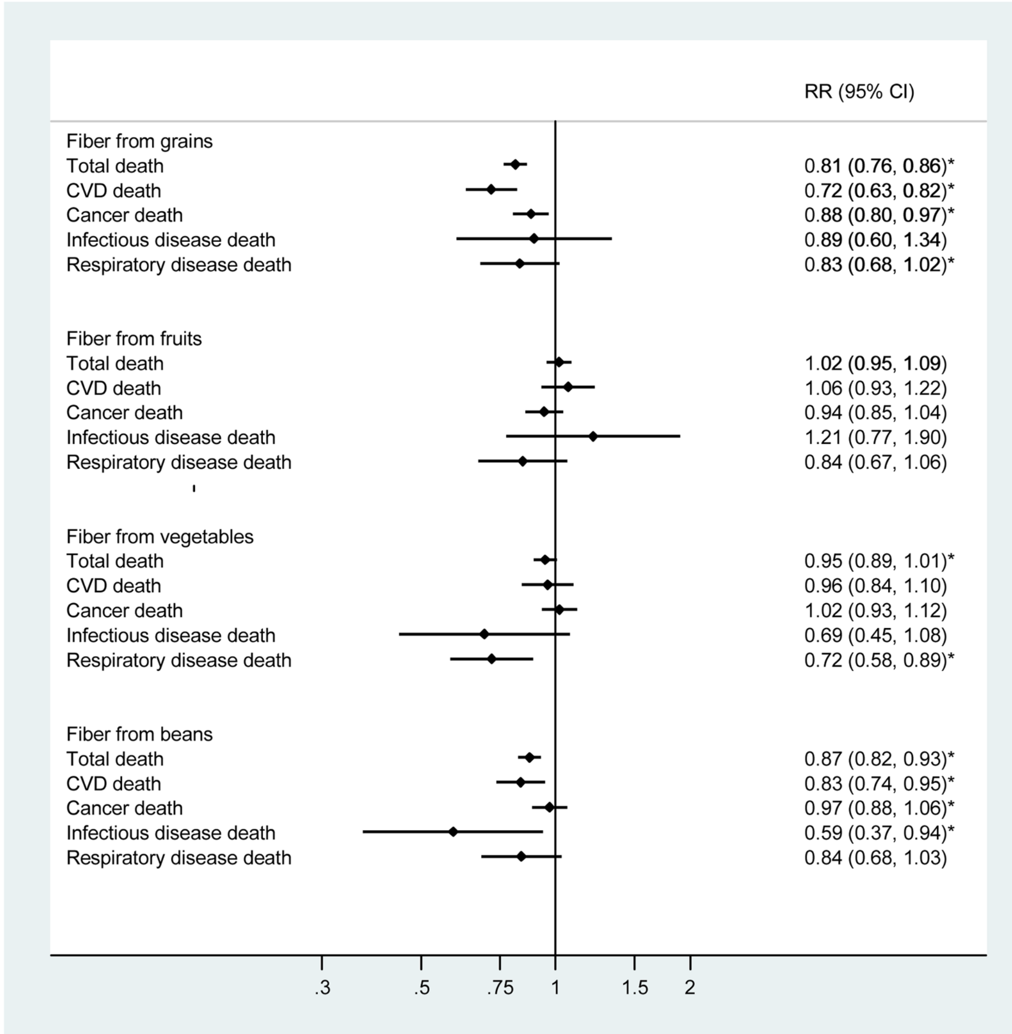
A. men



* P-trend <0.05

B. Women



* P-trend <0.05

Figure 1.
Multivariate relative risk of total and cause-specific death comparing the highest vs. the lowest quintile of fiber intake from food sources

Table 1

Selected characteristics of study participants by categories of dietary fiber intake

	Men			Women		
	Dietary fiber intake			Dietary fiber intake		
	Quintile 1	Quintile 3	Quintile 5	Quintile 1	Quintile 3	Quintile 5
Median dietary fiber intake (g/day)	12.6	19.4	29.4	10.8	17.0	25.8
Age at baseline [a]	61	62	62	61	62	62
White, non-Hispanic (%)	92	94	91	90	91	88
College and post college (%)	38	47	53	24	32	37
Married (%)	82	87	84	42	47	45
Excellent, very good health (%)	55	62	70	50	58	65
Body mass index [a]	27.3	27.2	26.4	26.8	26.6	25.6
Vigorous physical activity, ≥3 times/wk (%)	35	49	64	27	42	58
Former smoker (%)	50	55	54	33	38	41
Current smoker (%)	22	9	4	28	12	6
Current menopausal hormone therapy use (%)	-	-	-	41	47	47
Alcohol (g/day)[a]	27	19	9	12	5	3
Red meat (g/1,000 kcal)[a]	47	40	25	38	30	18
Total energy intake (kcal/day)[a]	2,019	2,084	1,969	1,565	1,573	1,524

[a] Mean values

Table 2

Relative risks and 95% confidence intervals of total death for quintiles of dietary fiber intake in men and women

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P trend
Men (median intake, g/day)	12.6	16.4	19.4	22.9	29.4	
Death (n)	5278	4292	3898	3453	3205	
Mortality rate[a]	1391	1081	957	824	747	
Age-adjusted	1.00	0.77 (0.74–0.81)	0.68 (0.66–0.71)	0.59 (0.56–0.61)	0.53 (0.51–0.56)	<0.001
Multivariate I[b]	1.00	0.90 (0.86–0.93)	0.86 (0.82–0.89)	0.78 (0.75–0.82)	0.75 (0.72–0.79)	<0.001
Multivariate II[c]	1.00	0.94 (0.90–0.98)	0.90 (0.86–0.94)	0.82 (0.78–0.87)	0.78 (0.73–0.82)	<0.001
Smoking status[d]						
Never smokers (n=3877)[e]	1.00	0.96 (0.86–1.08)	0.96 (0.86–1.08)	0.84 (0.74–0.95)	0.81 (0.71–0.93)	<0.001
Former smokers (n=10777)	1.00	0.91 (0.86–0.97)	0.87 (0.82–0.93)	0.81 (0.76–0.87)	0.76 (0.70–0.82)	<0.001
Current smokers (n=4502)	1.00	0.99 (0.91–1.07)	0.96 (0.88–1.06)	0.85 (0.76–0.95)	0.82 (0.70–0.95)	0.003
Body mass index[f]						
<25 (n=6307)	1.00	1.00 (0.93–1.08)	0.95 (0.87–1.03)	0.86 (0.78–0.94)	0.82 (0.74–0.92)	<0.001
25–<30 (n=8961)	1.00	0.93 (0.87–0.99)	0.92 (0.86–0.99)	0.82 (0.76–0.89)	0.79 (0.72–0.86)	<0.001
≥30 (n=4148)	1.00	0.86 (0.78–0.94)	0.79 (0.71–0.87)	0.78 (0.70–0.87)	0.74 (0.65–0.84)	<0.001
Women (median intake, g/day)	10.8	14.3	17.0	20.1	25.8	
Death (n)	3138	2651	2035	1949	1857	
Mortality rate	1067	743	641	613	583	
Age-adjusted	1.00	0.70 (0.67–0.74)	0.59 (0.56–0.63)	0.56 (0.53–0.59)	0.52 (0.50–0.56)	<0.001
Multivariate I	1.00	0.84 (0.79–0.88)	0.76 (0.72–0.80)	0.75 (0.70–0.79)	0.74 (0.70–0.78)	<0.001
Multivariate II	1.00	0.87 (0.83–0.93)	0.81 (0.76–0.86)	0.79 (0.73–0.85)	0.78 (0.73–0.85)	<0.001
Smoking status						
Never smokers (n=3259)	1.00	0.91 (0.81–1.02)	0.81 (0.71–0.92)	0.88 (0.77–1.01)	0.83 (0.72–0.97)	0.05
Former smokers (n=4284)	1.00	0.82 (0.74–0.90)	0.81 (0.73–0.90)	0.75 (0.67–0.84)	0.75 (0.66–0.86)	<0.001
Current smokers (n=3269)	1.00	0.94 (0.85–1.03)	0.84 (0.75–0.95)	0.76 (0.66–0.87)	0.86 (0.73–1.02)	0.003
Body mass index						
<25 (n=4783)	1.00	0.89 (0.82–0.98)	0.78 (0.71–0.87)	0.80 (0.72–0.90)	0.77 (0.68–0.87)	<0.001
25–<30 (n=3263)	1.00	0.84 (0.75–0.94)	0.80 (0.71–0.90)	0.73 (0.63–0.83)	0.79 (0.68–0.92)	0.002

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P trend
≥30 (n=2411)	1.00	0.88 (0.78–1.00)	0.89 (0.77–1.02)	0.87 (0.75–1.02)	0.81 (0.68–0.97)	0.04

[a] Per 100,000 person years, directly standardized to the age distribution of the cohort according to sex

[b] Multivariate model I adjusted for age, smoking status (never, former, and current), time since quitting(never, stopped ≥10 years ago, stopped 5–9 years ago, stopped 1–4 years ago, stopped <1 year ago, and currently smoking), and smoking dose (0, 1–10, 11–20, 21–30, 31–40, 41–50, 51–60, and >60 cigarettes/day).

[c] Multivariate model II adjusted for age, race/ethnicity (white, non-Hispanic; black, non-Hispanic; and others), education (less than high school, high school graduate, some college, and college graduate/ postgraduate), marital status (married and not married), health status (excellent, very good, good, fair and poor), body mass index (<18.5, 18.5–<25, 25–<30, and ≥30), physical activity (never/rare, ≤3 times/mo, and 1–2, 3–4, and ≥5 times/wk), smoking status (never, former, and current), time since quitting (never, stopped ≥10 years ago, stopped 5–9 years ago, stopped 1–4 years ago, stopped <1 year ago, and currently smoking), smoking dose (0, 1–10, 11–20, 21–30, 31–40, 41–50, 51–60, and >60 cigarettes/day), alcohol (0, >0–<5, 5–<15, 15–<30, 30–<40, ≥40 g/day), menopausal hormone therapy use in women (never, former, and current), and intakes of red meat (quintiles) total fruits and vegetables (quintiles), and total energy (continuous).

[d] Multivariate model adjusted for variables included in multivariate model II except for smoking status. Model for former smokers was also adjusted for time since quitting and a model for current smokers was adjusted for smoking dose.

[e] Number of death

[f] Multivariate model adjusted for variables included in multivariate model II. BMI in continuous scale was adjusted in each BMI category.

Table 3

Relative risks and 95% confidence intervals of cause-specific death for quintiles of dietary fiber intake in men

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P trend
Death from cardiovascular diseases						
Death (n)	1398	1099	965	922	864	
Age-adjusted	1.00	0.74 (0.69–0.81)	0.64 (0.59–0.69)	0.59 (0.54–0.64)	0.54 (0.49–0.59)	<0.001
Multivariate I[a]	1.00	0.85 (0.79–0.92)	0.78 (0.72–0.85)	0.76 (0.70–0.83)	0.73 (0.67–0.79)	<0.001
Multivariate II[b]	1.00	0.89 (0.82–0.96)	0.82 (0.75–0.90)	0.80 (0.73–0.89)	0.76 (0.68–0.85)	<0.001
Death from cancers						
Death (n)	2157	1786	1599	1410	1292	
Age-adjusted	1.00	0.79 (0.74–0.84)	0.69 (0.65–0.74)	0.59 (0.55–0.63)	0.53 (0.50–0.57)	<0.001
Multivariate I	1.00	0.94 (0.88–1.00)	0.89 (0.84–0.95)	0.83 (0.77–0.89)	0.79 (0.74–0.85)	<0.001
Multivariate II	1.00	0.98 (0.91–1.04)	0.94 (0.87–1.01)	0.87 (0.81–0.94)	0.83 (0.76–0.92)	<0.001
Death from infectious diseases						
Death (n)	70	58	55	56	36	
Age-adjusted	1.00	0.79 (0.55–1.11)	0.72 (0.51–1.03)	0.71 (0.50–1.02)	0.45 (0.30–0.67)	<0.001
Multivariate I	1.00	0.85 (0.60–1.20)	0.81 (0.57–1.16)	0.83 (0.58–1.19)	0.53 (0.35–0.80)	0.004
Multivariate II	1.00	0.87 (0.60–1.25)	0.81 (0.55–1.20)	0.81 (0.53–1.23)	0.44 (0.26–0.74)	0.003
Death from respiratory diseases						
Death (n)	481	337	262	190	145	
Age-adjusted	1.00	0.66 (0.57–0.75)	0.49 (0.42–0.57)	0.34 (0.29–0.41)	0.25 (0.21–0.31)	<0.001
Multivariate I	1.00	0.86 (0.75–0.99)	0.76 (0.66–0.89)	0.62 (0.52–0.73)	0.53 (0.44–0.64)	<0.001
Multivariate II	1.00	0.97 (0.84–1.13)	0.91 (0.77–1.08)	0.74 (0.61–0.90)	0.69 (0.54–0.87)	<0.001
Death from accidents						
Death (n)	169	148	149	126	142	
Age-adjusted	1.00	0.84 (0.68–1.05)	0.83 (0.67–1.04)	0.69 (0.55–0.87)	0.77 (0.61–0.96)	0.01
Multivariate I	1.00	0.93 (0.74–1.16)	0.96 (0.77–1.20)	0.82 (0.65–1.04)	0.93 (0.74–1.18)	0.43
Multivariate II	1.00	0.97 (0.77–1.22)	1.03 (0.80–1.31)	0.89 (0.68–1.18)	1.01 (0.74–1.36)	0.95
Death from other causes						
Death (n)	269	200	193	153	177	
Age-adjusted	1.00	0.70 (0.58–0.84)	0.66 (0.55–0.79)	0.50 (0.41–0.61)	0.57 (0.47–0.69)	<0.001

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P trend
Multivariate I	1.00	0.79 (0.66–0.95)	0.79 (0.66–0.96)	0.64 (0.52–0.78)	0.75 (0.62–0.92)	0.002
Multivariate II	1.00	0.85 (0.70–1.03)	0.83 (0.68–1.02)	0.65 (0.51–0.82)	0.71 (0.55–0.92)	0.004

[a]Multivariate model I adjusted for age, smoking status (never, former, and current), time since quitting (never, stopped ≥10 years ago, stopped 5–9 years ago, stopped 1–4 years ago, stopped <1 year ago, and currently smoking), and smoking dose (0, 1–10, 11–20, 21–30, 31–40, 41–50, 51–60, and >60 cigarettes/day).

[b]Multivariate model II adjusted for age, race/ethnicity (white, non-Hispanic; black, non-Hispanic; and others), education (less than high school, high school graduate, some college, and college graduate/postgraduate), marital status (married and not married), health status (excellent, very good, good, fair and poor), body mass index (<18.5, 18.5–<25, 25–<30, and ≥30), physical activity (never/rare, ≤3 times/mo, and 1–2, 3–4, and ≥5 times/wk), smoking status (never, former, and current), time since quitting (never, stopped ≥10 years ago, stopped 5–9 years ago, stopped 1–4 years ago, stopped <1 year ago, and currently smoking), smoking dose (0, 1–10, 11–20, 21–30, 31–40, 41–50, 51–60, and >60 cigarettes/day), alcohol (0, >0–<5, 5–<15, 15–<30, 30–<40, ≥40 g/day), and intakes of red meat (quintiles) total fruits and vegetables (quintiles), and total energy (continuous).

Table 4

Relative risks and 95% confidence intervals of cause-specific death for quintiles of dietary fiber intake in women

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P trend
Death from cardiovascular diseases						
Death (n)	683	510	444	409	371	
Age-adjusted	1.00	0.69 (0.62–0.78)	0.58 (0.52–0.66)	0.53 (0.46–0.59)	0.47 (0.41–0.53)	<0.001
Multivariate I[a]	1.00	0.82 (0.73–0.92)	0.74 (0.66–0.84)	0.70 (0.62–0.79)	0.66 (0.57–0.75)	0.001
Multivariate II[b]	1.00	0.85 (0.75–0.96)	0.78 (0.68–0.90)	0.72 (0.61–0.84)	0.66 (0.55–0.79)	<0.001
Death from cancers						
Death (n)	1313	1017	888	849	860	
Age-adjusted	1.00	0.73 (0.68–0.80)	0.63 (0.58–0.68)	0.59 (0.54–0.64)	0.59 (0.54–0.64)	<0.001
Multivariate I	1.00	0.90 (0.83–0.97)	0.83 (0.76–0.91)	0.82 (0.75–0.90)	0.88 (0.80–0.96)	0.001
Multivariate II	1.00	0.93 (0.85–1.01)	0.88 (0.80–0.97)	0.88 (0.79–0.98)	0.96 (0.85–1.08)	0.48
Death from infectious diseases						
Death (n)	66	45	36	46	30	
Age-adjusted	1.00	0.64 (0.43–0.93)	0.49 (0.33–0.74)	0.62 (0.42–0.90)	0.40 (0.26–0.61)	<0.001
Multivariate I	1.00	0.73 (0.50–1.07)	0.60 (0.39–0.90)	0.77 (0.52–1.13)	0.52 (0.33–0.80)	0.009
Multivariate II	1.00	0.67 (0.44–1.00)	0.53 (0.33–0.84)	0.64 (0.40–1.04)	0.41 (0.23–0.73)	0.006
Death from respiratory diseases						
Death (n)	386	226	178	136	105	
Age-adjusted	1.00	0.54 (0.46–0.63)	0.41 (0.34–0.49)	0.30 (0.25–0.37)	0.23 (0.19–0.29)	<0.001
Multivariate I	1.00	0.70 (0.59–0.82)	0.60 (0.50–0.72)	0.48 (0.39–0.58)	0.40 (0.32–0.50)	<0.001
Multivariate II	1.00	0.81 (0.68–0.97)	0.73 (0.59–0.90)	0.58 (0.46–0.74)	0.54 (0.40–0.72)	<0.001
Death from accidents						
Death (n)	60	64	34	69	58	
Age-adjusted	1.00	1.02 (0.72–1.45)	0.53 (0.35–0.81)	1.07 (0.76–1.51)	0.89 (0.62–1.28)	0.74
Multivariate I	1.00	1.12 (0.78–1.60)	0.60 (0.39–0.92)	1.23 (0.86–1.76)	1.05 (0.72–1.52)	0.60
Multivariate II	1.00	1.07 (0.73–1.57)	0.56 (0.35–0.91)	1.08 (0.70–1.69)	0.77 (0.46–1.28)	0.38
Death from other causes						
Death (n)	180	103	102	87	101	
Age-adjusted	1.00	0.53 (0.42–0.68)	0.51 (0.40–0.65)	0.43 (0.33–0.55)	0.49 (0.38–0.62)	<0.001

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	P trend
Multivariate I	1.00	0.61 (0.48–0.78)	0.62 (0.48–0.79)	0.53 (0.41–0.69)	0.63 (0.49–0.82)	0.004
Multivariate II	1.00	0.67 (0.52–0.87)	0.68 (0.51–0.91)	0.56 (0.40–0.77)	0.60 (0.42–0.85)	0.006

[a]Multivariate model I adjusted for age, smoking status (never, former, and current), time since quitting (never, stopped ≥10 years ago, stopped 5–9 years ago, stopped 1–4 years ago, stopped <1 year ago, and currently smoking), and smoking dose (0, 1–10, 11–20, 21–30, 31–40, 41–50, 51–60, and >60 cigarettes/day).

[b]Multivariate model II adjusted for age, race/ethnicity (white, non-Hispanic; black, non-Hispanic; and others), education (less than high school, high school graduate, some college, and college graduate/postgraduate), marital status (married and not married), health status (excellent, very good, good, fair and poor), body mass index (<18.5, 18.5–<25, 25–<30, and ≥30), physical activity (never/rare, ≤3 times/mo, and 1–2, 3–4, and ≥5 times/wk), smoking status (never, former, and current), time since quitting (never, stopped ≥10 years ago, stopped 5–9 years ago, stopped 1–4 years ago, stopped <1 year ago, and currently smoking), smoking dose (0, 1–10, 11–20, 21–30, 31–40, 41–50, 51–60, and >60 cigarettes/day), alcohol (0, >0–<5, 5–<15, 15–<30, 30–<40, ≥40 g/day), menopausal hormone therapy use (never, former, and current), and intakes of red meat (quintiles) total fruits and vegetables (quintiles), and total energy (continuous).