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Systematic Reviews and Meta- and Pooled Analyses

Dietary Fiber Intake and Total Mortality: A Meta-Analysis of Prospective Cohort Studies

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Greater intake of dietary fiber has been associated with lower risk of several chronic diseases. Some observational studies have examined the association between dietary fiber intake and total mortality, but the results were inconclusive. We conducted a meta-analysis of data from prospective cohort studies to quantitatively assess the association. Eligible studies were identified by searching the PubMed and Embase databases for all articles published through November 30, 2013, and by reviewing the reference lists of retrieved articles. Study-specific estimates adjusting for potential confounders were combined to calculate a pooled relative risk and 95% confidence interval using a random-effects model. Seven prospective cohort studies of dietary fiber intake and total mortality, including 62,314 deaths among 908,135 participants, were identified. The pooled adjusted relative risk of total mortality for the highest category of dietary fiber intake versus the lowest was 0.77 (95% confidence interval: 0.74, 0.80). In a dose-response meta-analysis, the pooled adjusted relative risk for a 10-g/day increment of dietary fiber intake was 0.89 (95% confidence interval: 0.85, 0 92). By source of fiber, cereal and, to a lesser extent, vegetable fiber were significantly associated with lower total mortality, while fruit fiber showed no association. In conclusion, high dietary fiber intake may reduce the risk of total mortality.

death; diet; fiber; meta-analysis; mortality; prospective cohort studies

Abbreviations: BMI, body mass index; CI, confidence interval; RR, relative risk.

Dietary fiber is defined as the parts of plant foods that are indigestible by humans; it includes polysaccharides, lignin, and oligosaccharides (1). Generally, dietary fiber has been associated with decreased constipation and improved intestinal health. In addition, it provides many other health benefits, including decreasing plasma lipid levels (2), lowering blood pressure (3), stabilizing blood glucose levels (4), and reducing inflammation (5). Accumulating evidence from observational studies indicates that dietary fiber could act as a protective factor against diseases such as stroke (6), some types of cancer (7, 8), type 2 diabetes (9), and cardiovascular disease (10), which are major causes of death. A relatively small number of observational studies have been performed to investigate the relationship between fiber intake and total mortality, and the results were inconsistent (11–17). Thus, we conducted a systematic review and meta-analysis of data from prospective cohort studies to quantitatively assess the association between fiber intake and total mortality.

METHODS

Literature search

We searched electronic databases (PubMed and Embase) to identify eligible studies published in English through November 30, 2013. The following search terms were used: "(fiber or fibre)" combined with "(total mortality, all-cause mortality, death, or survival)." In addition, we manually searched the reference lists of retrieved articles or published reviews to identify further relevant studies.

Study selection

Studies were included in this meta-analysis if they met the following criteria: 1) they were prospective cohort studies, 2) the exposure of interest was dietary fiber intake, 3) the outcome of interest was defined as total or all-cause mortality, and 4) they reported relative risks and 95% confidence intervals or sufficient data for calculating them. Studies conducted in patients who had specific diseases were not included.

Data extraction

Data were extracted independently by 2 investigators (Y.K. and Y.J.) according to the Meta-Analysis of Observational Studies in Epidemiology (MOOSE) guidelines (18; also Web Table 1, available at http://aje.oxfordjournals.org/), and discrepancies were resolved through reviewing the original reports and discussion. From each study, the following information was extracted: first author's surname; year of publication; geographical region; duration of follow-up or dates of study period; sex; age; number of events; number of subjects or person-time; adjustment for potential confounders; and relative risk estimates with corresponding 95% confidence intervals for each category of dietary fiber intake. If the published article provided several relative risks on this subject, we chose the relative risk from the most fully adjusted multivariable model.

Quality assessment

The quality of each study was assessed independently by 2 investigators (Y.K. and Y.J.) using the Newcastle-Ottawa quality assessment scale (19) for the following items: representativeness of the exposed cohort; method of fiber intake measurement; comparability of cohorts on the basis of the study design or analysis—that is, adjustment for important confounders (age, body mass index (BMI; weight (kg)/height (m)^2), smoking, alcohol drinking, and physical activity); assessment of outcome; duration of follow-up; and adequacy of follow-up. Disagreements between the investigators on more than 1 score were resolved by consensus. A score of 10 or higher (out of 13) indicates a high-quality study, scores of 7–9 indicate a good-quality study, and a score of 6 or less indicates a low-quality study.

Statistical analysis

We calculated the pooled relative risk of total mortality (and its 95% confidence interval) for the highest category of dietary fiber intake versus the lowest category from the original studies using DerSimonian and Laird random-effects models, which incorporate both within- and between-study variation (20). For studies that reported relative risks for both dietary fiber intake from each food and total dietary fiber intake, we used the results for total dietary fiber intake in the main analysis. If a study provided both an overall relative risk and a sex-specific relative risk (13), we included the overall relative risk in the main analysis, since the relative risks in men and women did not vary. However, the sex-specific relative risks were used in the meta-analysis by sex. The pooled relative risk and the study-specific relative risks are presented as forest plots wherein the size of data markers (squares) corresponds to the inverse of the variance of the natural logarithm of the relative risk from each study and the diamond indicates the pooled relative risk. To assess statistical heterogeneity among the studies, we used the Q statistic (21), and inconsistency was quantified by means of the I^2 statistic (22). For a dose-response meta-analysis, we used the 2-stage generalized least-squares trend estimation method to estimate the study-specific slope lines first and then derive an overall average slope, using the method developed by Greenland, Longnecker, and colleagues (23–25), and calculated a pooled relative risk for a 10-g/day increment of dietary fiber intake. Two studies were excluded, because one study did not report information on numbers of deaths and person-time across categories of dietary fiber intake (16) and the other study had only 2 categories of dietary fiber intake (17). Therefore, 5 studies were included in the dose-response meta-analysis (11–15).

To examine the variations in risk estimates among the studies, we carried out subgroup analyses stratified by sex, geographical region (Europe/United States/Middle East), follow-up time (shorter/longer than the median follow-up time), adjustment for covariates (age, smoking, alcohol, BMI, and physical activity), and source of dietary fiber (cereals/vegetables/fruits/beans). To test for variations in pooled relative risks among the subgroups, we conducted meta-regression analyses with the log relative risk modeled as a dependent variable and study variables modeled as explanatory variables. We also conducted sensitivity analyses that excluded one study at a time, to assess the influence of individual studies by creating a sensitivity plot. Finally, publication bias was assessed using the tests of Begg and Mazumdar (26) and Egger et al. (27). A 2-tailed P value less than 0.05 was considered statistically significant. All statistical analyses were conducted using Stata/SE software, version 12.0 (StataCorp LP, College Station, Texas).

RESULTS

Study characteristics

We identified 7 prospective cohort studies (11–17), including 908,135 individuals and 62,314 deaths, that were eligible for the present meta-analysis (Figure 1). Three studies provided relative risks for categories of dietary fiber intake and total mortality (14, 16, 17), 3 studies provided relative risks for dietary fiber intake as a continuous variable (11, 12, 15), and 1 study presented relative risks for categories of dietary fiber intake as well as dietary fiber intake as a continuous variable (13). The main characteristics of the included studies are presented in Table 1. The follow-up periods of the 7 studies ranged from 7.7 years to 40 years, and the mean follow-up time was 17.6 years. The participants were all adults aged ≥25 years at baseline. By geographical region, 4 studies were performed in Europe (11, 13, 15, 16), 2 were performed in the United States (12, 14), and 1 was performed in the Middle East (17). With regard to sex, 5 studies included both male and female subjects (11, 13, 14, 16, 17) and 2 studies included male (15) or female (12) subjects only. Three studies provided relative risks for men and women separately (13, 14, 16). Four studies reported relative risks by food source of fiber (12–15). All studies except 1 (15), which used the cross-check dietary history method, used a food frequency questionnaire to assess exposure to dietary fiber. All of the studies adjusted for age, BMI, smoking, and total energy intake.

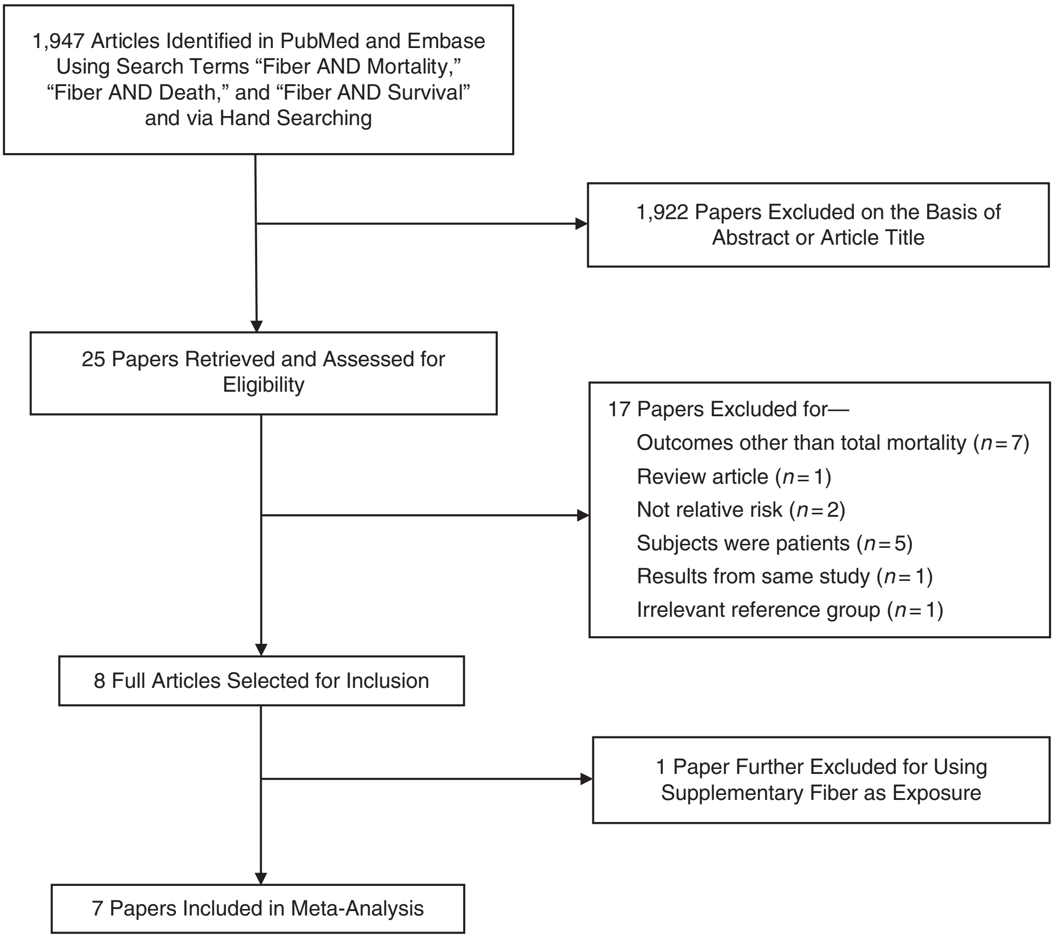

Figure 1. Process used to select prospective cohort studies for a meta-analysis of the association between dietary fiber intake and total mortality, 1964–2013.

Most of the studies provided risk estimates that were adjusted for potential confounders such as alcohol consumption (12–16) and physical activity (11–14, 16, 17). Regarding quality assessment, the studies included in the meta-analysis had a mean quality assessment score of 9.7 (range, 8–13) out of a possible 13. Three studies had a score of more than 10, indicating high quality (15–17), and the other studies had a score of 8 or 9, indicating good quality (11–14).

Highest dietary fiber intake versus lowest

Four studies with a total of 55,839 cases were included in the meta-analysis of highest category of dietary fiber intake versus the lowest. Figure 2 shows multivariable-adjusted relative risks for the highest versus lowest categories of dietary fiber intake for each study and all studies combined. The pooled relative risk of total mortality for all studies was 0.77 (95% confidence interval (CI): 0.74, 0.80), with no significant heterogeneity among study results ($P = 0.60$, $I^2 = 0.0\%$). When we excluded one study at a time and calculated the pooled relative risk with the remaining studies, the pooled relative risks ranged from 0.75 (95% CI: 0.72, 0.79) to 0.77 (95% CI: 0.74, 0.81), which provided robust results (Web Figure 1).

The results of subgroup analyses are presented in Table 2. By sex, the inverse association tended to be stronger for men (relative risk (RR) = 0.73, 95% CI: 0.66, 0.81) than for women (RR = 0.79, 95% CI: 0.75, 0.83), but the difference was not statistically significant (for men vs. women, $P = 0.31$). By geographical region, the relative risks for studies conducted in Europe, the United States, and the Middle East were 0.76 (95% CI: 0.72, 0.80), 0.78 (95% CI: 0.74, 0.82), and 0.57 (95% CI: 0.36, 0.90), respectively, and no significant difference by region was found. For the periods of follow-up, we choose a median follow-up time of 11 years as a cutoff. The pooled relative risks for long follow-up periods (≥11 years; RR = 0.72, 95% CI: 0.58, 0.90) and short follow-up periods (<11 years; RR = 0.78, 95% CI: 0.74, 0.81) were similar (for long follow-up vs. short follow-up, $P = 0.51$). When analysis was limited to 3 studies that had adjusted for age, BMI, smoking, alcohol drinking, and physical activity (13, 14, 16), the inverse association was the same as the

Table 1. Characteristics of Prospective Cohort Studies Included in a Meta-Analysis of Dietary Fiber Intake and Total Mortality, 1999–2012

First Author, Year (Reference No.)	Location of Study	Name of Study or Cohort	Study Period	Duration of Follow-up, years	Age Range, years	Study Size		Sex of Subjects	Adjustment Factors
						No. of Subjects	No. of Deaths		
Todd, 1999 (16)	Scotland, United Kingdom	Scottish Heart Health Study	1984–1993	7.7	40–59	4,036	242	Men	Age, serum total cholesterol, systolic blood pressure, carbon monoxide, energy intake, previous medical diagnosis of diabetes, BMI,[a] Bortner personality score (45), triglycerides, high-density lipoprotein cholesterol, fibrinogen, self-reported leisure-time activity, and alcohol consumption
Todd, 1999 (16)	Scotland, United Kingdom	Scottish Heart Health Study	1984–1993	7.7	40–59	3,833	108	Women	As above
Lubin, 2003 (17)	Israel	Israel Glucose Intolerance, Obesity and Hypertension Study	1982–2000	18	41–70	623	151	Men and women	Age, sex, BMI, smoking status, ethnic origin, systolic blood pressure, physical activity, mean daily energy intake, fatty acid intake, energy intake from fat, and cholesterol intake
Streppel, 2008 (15)	The Netherlands	Zutphen Study	1960–2000	40	49 (6)[b]	1,373	1,048	Men	Age; total energy intake; intakes of saturated fat, *trans*-unsaturated fatty acid, and *cis*-polyunsaturated fat; alcohol intake; wine use; fish intake; prescribed diet; number of cigarettes smoked per day; duration of cigarette smoking; cigar or pipe smoking; BMI; and socioeconomic status
Park, 2011 (14)	United States	NIH-AARP Diet and Health Study	1995–2005	9	50–71	219,123	20,126	Men	Age, race/ethnicity, education, marital status, health status, BMI, physical activity, smoking status, time since quitting smoking, number of cigarettes smoked per day, alcohol intake, menopausal hormone therapy (women), and intakes of red meat, total fruits and vegetables, and total energy
Park, 2011 (14)	United States	NIH-AARP Diet and Health Study	1995–2005	9	50–71	168,999	11,630	Women	As above
Akbaraly, 2011 (11)	United Kingdom	Whitehall II cohort	1985–2010	18	39–63	7,319	534	Men and women	Age, modified total AHEI score that excluded the component considered in the analysis, sex, ethnicity, occupational grade, marital status, smoking status, total energy intake, physical activity, BMI category, prevalent cardiovascular disease, type 2 diabetes, hypertension, dyslipidemia, metabolic syndrome, and inflammatory markers
Baer, 2011 (12)	United States	Nurses' Health Study	1986–2004	18	30–55	50,112	4,893	Women	Age, BMI, energy intake, weight change since age 18 years, height, smoking status, smoking amount/duration, physical activity, alcohol intake, nut consumption, polyunsaturated fat intake, glycemic load, dietary cholesterol intake, systolic blood pressure, use of blood pressure medication, personal history of diabetes, parental myocardial infarction before age 60 years, and time since menopause
Chuang, 2012 (13)	Europe	EPIC Study	1992–2009	12.7	25–70	452,717	23,582	Men and women	Age, education, smoking, alcohol consumption, BMI, physical activity, and total energy intake

Abbreviations: AHEI, Alternative Healthy Eating Index; BMI, body mass index; EPIC, European Prospective Investigation into Cancer and Nutrition; NIH, National Institutes of Health.

[a] Weight (kg)/height (m)^2.

[b] The mean value and standard deviation are shown. No age range was given in the published article.

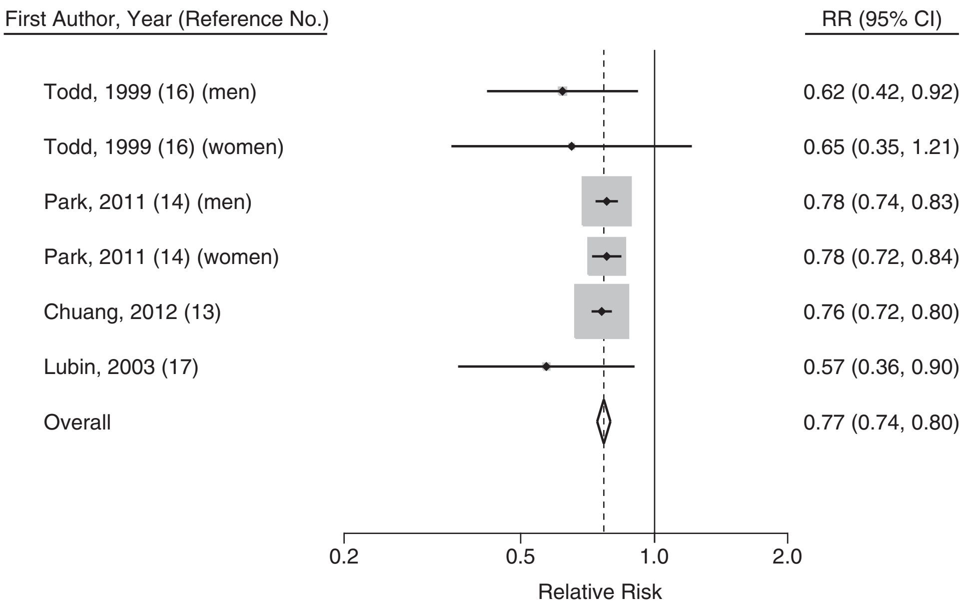

Figure 2. Pooled and study-specific relative risks (RRs) of total mortality among persons in the highest category of dietary fiber intake versus the lowest (random-effects model), 1999–2012. The sizes of the squares correspond to the inverse of the variance of the natural logarithm of the relative risk from each prospective cohort study, and the diamond indicates the pooled relative risk. Horizontal lines, 95% confidence intervals (CIs).

result for all studies (RR = 0.77, 95% CI: 0.74, 0.80). One study provided relative risks stratified by dietary fiber source for the highest versus lowest intakes (14); dietary fiber intake from grains showed a strong inverse association with total mortality in both men (RR = 0.77, 95% CI: 0.73, 0.81) and women (RR = 0.81, 95% CI: 0.76, 0.86). Intake of dietary fiber from vegetables or beans showed a slight inverse association, but fruit fiber showed no association in either men (RR = 1.03, 95% CI: 0.99, 1.09) or women (RR = 1.02, 95% CI: 0.95, 1.09) (14).

Dose-response meta-analysis

Five studies with a total of 61,921 cases were included in the dose-response meta-analysis of dietary fiber intake and total mortality. The pooled relative risk for a 10-g/day increment of dietary fiber intake was 0.89 (95% CI: 0.85, 0.92), with some evidence of significant heterogeneity ($P < 0.001$, $I^2 = 77.5\%$) (Figure 3). The sensitivity analyses carried out by omitting one study at a time provided pooled relative risks ranging from 0.85 (95% CI: 0.82, 0.88) to 0.90 (95% CI: 0.87, 0.94) (Web Figure 1). After exclusion of 1 study (14), the significant heterogeneity disappeared ($P = 0.384$, $I^2 = 1.7\%$).

The inverse associations between dietary fiber intake and total mortality were similar for men (RR = 0.89, 95% CI: 0.82, 0.97) and women (RR = 0.85, 95% CI: 0.80, 0.92) (for men vs. women, $P = 0.42$) (Table 2). No significant difference was found by geographical region (for Europe vs. United States, $P = 0.53$), by follow-up period (for <18 years vs. ≥18 years, $P = 0.62$), or by adjustment for age, smoking, alcohol drinking, BMI, and physical activity ($P =$ 0.67). By source of dietary fiber, we found a significant inverse association for cereal fiber (RR = 0.92, 95% CI: 0.88, 0.95) and, to a lesser extent, vegetable fiber (RR = 0.95, 95% CI: 0.90, 1.00), while no association was found with fruit fiber (RR = 0.99, 95% CI: 0.97, 1.02) (for cereal fiber vs. fruit fiber, $P = 0.05$). Only 1 study reported a result for dietary intake of fiber from beans (14); bean fiber had a nonsignificant inverse association with total mortality (RR = 0.91, 95% CI: 0.61, 1.35).

Publication bias

For the meta-analysis of dietary fiber intake in increments of 10 g/day ($n = 5$ studies), there was no evidence of publication bias (Begg's $P > 0.99$; Egger's $P = 0.20$). For the meta-analysis of the highest category of dietary fiber intake versus the lowest ($n = 4$ studies), the Egger regression asymmetry test showed suggestive (but not significant) evidence of bias ($P = 0.05$); however, evidence of bias was not shown in Begg's test ($P = 0.45$).

DISCUSSION

The results of the present meta-analysis indicated that dietary fiber intake is inversely associated with total mortality. Based on the meta-analysis of the highest category of dietary fiber intake (mean ≈ 26.9 g/day) versus the lowest (mean ≈ 15.0 g/day), people with a high fiber intake had a 23% lower risk of total mortality than those who had a relatively low fiber intake. The inverse association did not vary by sex or geographical region. The results of the dose-response meta-analysis suggested that each additional 10 g of fiber intake

Table 2. Pooled Relative Risk of Total Mortality According to Dietary Fiber Intake in a Meta-Analysis of Prospective Cohort Studies, 1999–2012

Variable	No. of Studies	Relative Risk	95% Confidence Interval	*P* for Difference
High Fiber Intake Versus Low Fiber Intake				
All studies	4	0.77	0.74, 0.80	
Sex				
Male	3	0.73	0.66, 0.81	0.31
Female	3	0.79	0.75, 0.83	
Geographical region				
Europe	2	0.76	0.72, 0.80	
United States	1	0.78	0.74, 0.82	0.45[a]
Middle East	1	0.57	0.36, 0.90	0.32[a]
Follow-up time, years[b]				
<11	2	0.78	0.74, 0.81	0.51
≥11	2	0.72	0.58, 0.90	
Adjustment for age, smoking, BMI,[c] alcohol drinking, and physical activity				
Yes	3	0.77	0.74, 0.80	0.27
No	1	0.57	0.36, 0.90	
Newcastle-Ottawa score[d]				
≥9	3	0.75	0.72, 0.79	0.39
<9	1	0.78	0.74, 0.82	
10-g/day Increment of Fiber Intake				
All studies	5	0.89	0.85, 0.92	
Sex				
Male	3	0.89	0.82, 0.97	0.42
Female	3	0.85	0.80, 0.92	
Geographical region				
Europe	3	0.86	0.81, 0.92	0.53
United States	2	0.90	0.86, 0.94	
Follow-up time, years[e]				
<18	3	0.89	0.85, 0.94	0.62
≥18	2	0.87	0.80, 0.94	
Adjustment for age, smoking, BMI, alcohol drinking, and physical activity				
Yes	3	0.88	0.84, 0.92	0.67
No	2	0.91	0.83, 1.01	
Source of dietary fiber				
Cereals	3	0.92	0.88, 0.95	
Vegetables	2	0.95	0.90, 1.00	0.32[f]
Fruits	2	0.99	0.97, 1.02	0.05[f]
Beans	1	0.91	0.61, 1.35	0.98[f]
Newcastle-Ottawa score				
≥9	4	0.85	0.82, 0.88	0.05
<9	1	0.92	0.89, 0.94	

Abbreviation: BMI, body mass index.

[a] *P* value for the difference in relative risks: United States versus Europe, *P* = 0.45; Middle East versus Europe, *P* = 0.32. For studies conducted in the United States versus the Middle East, the *P* value for the difference was 0.27.

[b] The median follow-up time for studies included in the analysis of highest intake versus lowest intake was 11 years.

[c] Weight (kg)/height (m)^2.

[d] Score on the Newcastle-Ottawa quality assessment scale (possible range, 0–13) (19).

[e] The median follow-up time for studies included in the analysis of a 10-g/day increment was 18 years.

[f] *P* value for the difference in relative risks (when all sources of dietary fiber were included in the meta-regression model simultaneously): vegetables versus cereals, *P* = 0.32; fruits versus cereals, *P* = 0.046; beans versus cereals, *P* = 0.98.

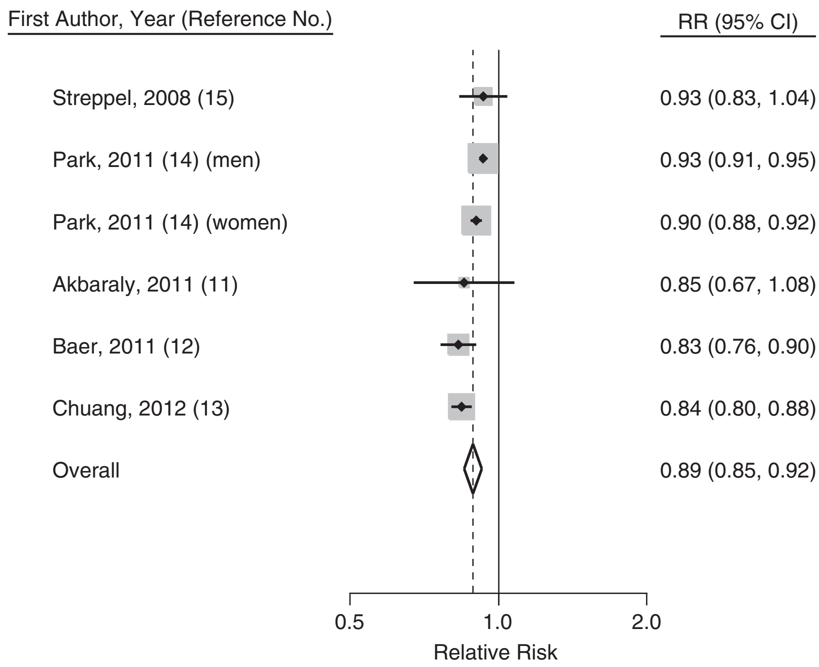

Figure 3. Pooled and study-specific relative risks (RRs) of total mortality for a 10-g/day increment of dietary fiber intake (random-effects model), 2008–2012. The sizes of the squares correspond to the inverse of the variance of the natural logarithm of the relative risk from each prospective cohort study, and the diamond indicates the pooled relative risk. Horizontal lines, 95% confidence intervals (CIs).

daily may lower the risk of total mortality by 11%. By source of fiber, cereal and to a lesser extent vegetable fiber were significantly associated with lower total mortality, while fruit fiber showed no association.

Accumulating evidence from observational studies has shown significant inverse associations between dietary fiber intake and risks of several chronic diseases, including stroke, type 2 diabetes, colorectal adenoma, gastric cancer, and breast cancer, all of which could affect total mortality (6, 28–31). Several potential mechanisms may explain the beneficial role of dietary fiber intake in the risks of chronic diseases. Dietary fiber intake has been associated with increased satiety resulting from the prolonged time needed for nutrient absorption and delayed gastric emptying (32, 33), as well as reduced postprandial glucose responses (34–36). High dietary fiber intake has also been associated with decreased serum cholesterol levels by reducing the absorption of cholesterol from the small intestine and increasing the excretion of bile acids in feces (37–39). In addition, dietary fiber intake is associated with lower levels of inflammatory markers such as C-reactive protein, interleukin-6, and tumor necrosis factor α (5, 40–42). Short-chain fatty acids, which are produced from fermentation of dietary fiber by microbiota, function as a key regulator of antiinflammatory actions (43). These characteristics of dietary fiber intake may decrease the incidence of chronic diseases and thus help reduce the risk of death from these diseases.

Several studies that examined the association between fiber intake from different foods and disease risk reported that cereal fiber was strongly associated with lower risks of colorectal cancer, gastric cancer, type 2 diabetes, and stroke, while vegetable fiber or fruit fiber was weakly associated with disease risk (6, 28–30). The results were similar to our findings in that cereal fiber showed the strongest inverse association with total mortality. However, the results from these subgroup analyses should be interpreted with caution, because relatively few studies were included in our analysis of fiber intake from different food sources.

Among the 7 studies included in this meta-analysis, 5 studies also reported relative risks of cardiovascular disease–specific mortality (11–15). Three studies showed significant inverse trends for dietary fiber intake (12–14), and 2 studies showed a nonsignificant, weak inverse association between dietary fiber intake and death from cardiovascular disease (11, 15). Three studies provided risk estimates for death from cancer along with total mortality (12–14). One study from Europe showed a significant inverse association between dietary fiber intake and death from all cancers in men and women (13), and another study from the United States found a significant inverse association in men but not in women (14). In the analyses stratified by cancer type, the inverse association was found only for smoking-related cancers, including cancers of the oral cavity, esophagus, stomach, colorectum, liver, pancreas, lung, and kidney (13). On the contrary, in the Nurses' Health Study, Baer et al. (12) reported a significant inverse association with non-smoking-related cancers but not with smoking-related cancers.

We found no evidence of heterogeneity among the studies for the analysis of high dietary fiber intake versus low intake.

In the dose-response analysis, however, there was some evidence of heterogeneity among the studies. The sensitivity analysis showed that the significant heterogeneity observed in the dose-response analysis disappeared after exclusion of 1 study ($I^2 = 1.7\%$, $P = 0.384$); this was the largest study and it had a relatively short follow-up period (<10 years), showing modest inverse associations in both men and women (14).

Our present meta-analysis had some strengths. To the best of our knowledge, this was the first comprehensive meta-analysis to explore the relationship between dietary fiber intake and total mortality. All of the studies included in this meta-analysis were prospective cohort studies. A prospective study design can minimize the possibility that the results were affected by recall or selection bias, which could be of concern in case-control studies. In addition, we included a large number of cases ($n = 62{,}314$) and subjects ($n = 908{,}135$) in the meta-analysis, which provided good statistical power for evaluating the association between dietary fiber intake and total mortality risk. Although a limited number of studies examined the association between dietary fiber from different food sources and total mortality, our findings may be useful for generating a hypothesis for future research. The quality assessment indicated that all of the studies included in the meta-analysis were of either high quality or relatively good quality, and the majority of studies adjusted for important confounders, including BMI, smoking, alcohol drinking, and physical activity.

Despite these strengths, several limitations also need to be acknowledged. First, some nondifferential misclassification of dietary fiber intake may have occurred in each study and thus in the meta-analysis, which may have attenuated any true association between dietary fiber intake and total mortality to some extent. All of the studies included in the meta-analysis assessed dietary fiber intake at a single time, except for 1 study that measured dietary fiber intake repeatedly (15). Some possible exposure misclassification may be especially high for studies with long-follow-up periods that assessed dietary fiber intake at baseline only. However, the subgroup analyses by follow-up period in our meta-analysis showed no significant difference in relative risks between the studies with short follow-up periods and the studies with long follow-up periods. Second, because our quantitative assessment was based on observational studies, we cannot rule out the possibility that unknown and/or residual confounding may still have affected the results in each study and thus the pooled estimates in the meta-analyses. Finally, in a meta-analysis of published studies, publication bias could be of concern. Although we found no significant evidence for publication bias, small studies that find no association are less likely to be published.

In conclusion, results from this meta-analysis of prospective cohort studies provide quantitative evidence regarding the inverse association between dietary fiber intake and total mortality. For practical reasons (including time and expense), it is hard to conduct experimental studies to investigate the association between dietary fiber intake and total mortality. Although the results of meta-analyses were based on the observational studies only, our findings may have public health implications, given that the mean dietary fiber intake in the United States and in many European countries (15 g/day) is less than half of recommended levels (28–36 g/day) (1, 44). Further well-designed large prospective cohort studies with repeated measurements of dietary fiber intake from different food sources, long-follow-up periods, and adjustment for all potential confounders are needed to verify the association of dietary fiber intake with total mortality.

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