

Whole-grain intake is inversely associated with the metabolic syndrome and mortality in older adults¹⁻³

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ABSTRACT

Background: Whole-grain intake has been inversely associated with the metabolic syndrome in middle-aged populations, but the association has not been investigated in older adults. The metabolic consequence of consuming high whole-grain diets may differ in elderly persons, who are prone to greater insulin resistance and impaired glucose tolerance.

Objective: The aim of the present study was to examine the cross-sectional association between whole- and refined-grain intake, cardiovascular disease risk factors, prevalence of the metabolic syndrome, and the incidence of cardiovascular disease mortality in the same cohort of older adults.

Design: The nutritional status of 535 healthy persons aged 60–98 y was determined from 1981 to 1984. The subjects kept a 3-d food record and had their blood tested for metabolic risk factors. The metabolic syndrome was defined based on criteria set by the third report of the National Cholesterol Education Program. The vital status of the subjects was identified in October 1995.

Results: The results showed a significant inverse trend between whole-grain intake and the metabolic syndrome (P for trend = 0.005) and mortality from cardiovascular disease (P for trend = 0.04), independent of demographic, lifestyle, and dietary factors. Fasting glucose concentrations and body mass index decreased across increasing quartile categories of whole-grain intake (P for trend = 0.01 and 0.03, respectively), independent of confounders, whereas intake of refined grain was positively associated with higher fasting glucose concentrations (P for trend = 0.04) and a higher prevalence of the metabolic syndrome (P for trend = 0.01).

Conclusion: Whole-grain intake is a modifiable dietary risk factor, and older and young adults should be encouraged to increase their daily intake to ≥ 3 servings/d. *Am J Clin Nutr* 2006;83:124–31.

KEY WORDS Food records, metabolic syndrome, mortality, older adults, whole grains

INTRODUCTION

For the first time, the *Dietary Guidelines for Americans* has provided a quantitative recommendation for the intake of whole grains, specifically that persons should consume ≥ 3 ounce-equivalents of whole-grain products per day (1). This recommendation was based on evidence that links whole-grain foods to a reduced risk of several chronic diseases, including cancer (2), type 2 diabetes (3, 4), and cardiovascular disease (CVD) (5–7). In contrast with whole grains, refined grains do not appear to offer protection (5, 7) and, in fact, may predispose some persons

to chronic disease (8). Whole-grain foods contain fiber, vitamins, minerals, phenolic compounds, phytoestrogens, and other unmeasured constituents that are removed during the refining process (9, 10). Despite being nutritionally inferior, most grain products consumed in the United States are refined, with the average older American consuming 5 servings of refined grains/d and < 1 serving of whole grains/d (11).

Diets that are rich in whole-grain foods have been linked to a lower prevalence of the metabolic syndrome (12, 13), a condition characterized by disturbed glucose and insulin metabolism, central obesity, mild dyslipidemia, and hypertension (14). The metabolic syndrome has been linked with an increased risk of both type 2 diabetes and CVD (15–17). Recent estimates indicate that the prevalence of the metabolic syndrome is increasing in the United States, with an estimated 40% of men and 51% women aged ≥ 60 y affected (18). The cause of this syndrome is largely unknown, but presumably represents a complex interaction between genetic, metabolic, and environmental factors, which includes diet (19–21). Whole-grain foods may confer protection through potential effects on weight gain or through direct effects of whole grain or its constituents on insulin sensitivity and other components of the metabolic syndrome.

Most observational studies have estimated dietary intakes of whole- and refined-grain foods with the use of a food-frequency questionnaire (FFQ) and related intake to metabolic risk factors and chronic diseases. To our knowledge, our study is the first to estimate grain intake by using diet records. Although all dietary methods are subject to measurement error, the open-ended format of the food diary provides a more quantitative estimation of grain intake, because it estimates the respective whole-grain and non-whole-grain ingredients from various foods, whereas the

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FFQ has a predefined set of foods. Moreover, until now, whole-grain intake has been related to metabolic risk factors in middle-aged populations rather than elderly persons. The metabolic consequence of consuming a high whole-grain diet is likely to differ in elderly persons who are prone to greater insulin resistance and impaired glucose tolerance. Finally, as far as we are aware, this is the first study to examine both the metabolic syndrome and mortality outcomes in the same population group. The purpose of the present study was to additionally examine the hypothesis that greater whole-grain intake is favorably associated with CVD risk factors, including a reduced prevalence of the metabolic syndrome and a reduced incidence in the risk of CVD mortality, in the same older adult population.

SUBJECTS AND METHODS

Subjects

The present study was conducted in Boston, MA, from 1981 to 1984. Nutrition information was collected from 747 community-living persons aged ≥ 60 y. The subjects were self-selected and recruited through presentations of the study to secular and religious groups and through contacts with community housing projects and neighborhood health clinics. The subjects had no severe metabolic disorders or diagnoses of terminal or wasting diseases. The study was approved by the Institutional Review Board at Tufts-New England Medical Center.

Of the 747 community-dwelling subjects who participated in the study, 126 persons were excluded from the analysis due to incomplete food records. Additionally, data from persons who were receiving insulin or oral glycemic agents ($n = 39$) or from those who had missing information on body weight ($n = 24$), biochemistry ($n = 15$), or smoking and exercise ($n = 8$) were excluded from the analysis. The final sample consisted of 535 subjects (179 men and 356 women) with a mean age of 72 y. These subjects included 127 (24%) subjects who were receiving lipid-lowering medication and 174 (33%) who were receiving blood pressure medication. The final sample was more educated (47% compared with 37%, $P < 0.05$) and had a lower fasting glucose concentration (\bar{x} concentration: 108.1 mg/dL compared with 129.6 mg/dL, $P < 0.05$) than did those who were excluded from the analyses. No significant differences in other lifestyle, dietary, biochemistry, or metabolic characteristics, including total energy intake and intake of whole and refined grains, were observed between the subjects and the persons who were excluded from the analyses.

Dietary intake

A dietitian instructed the subjects on how to keep a consecutive 3-d food record starting the day after the instructions were provided. The food records were then collected and reviewed by the dietitian for accuracy and completeness. Foods consumed were manually matched to the 8-digit US Department of Agriculture (USDA) food codes based on the Pyramid Servings database (USDA Survey Food Codes version 2) (22). For each food consumed, the total number of grain servings per 100 g food was determined by the Community Nutrition Research at Agricultural Research Services (ARS), USDA. This total number of grain servings was then divided into whole-grain servings and refined-grain servings on the basis of the proportion of the grain ingredients in the food that were whole grain and refined grain.

The gram amount of each food consumed was then added for whole grain and refined grain separately. Three-day intakes were summed, averaged, and reported as the mean intake of pyramid servings for whole grain or refined grain, separately.

Biochemical profile

An overnight fasting blood sample was obtained by venipuncture. Plasma total cholesterol and HDL cholesterol were measured by enzymatic spectrophotometry. The sample was treated with magnesium-phosphotungstate to isolate and collect the HDL cholesterol precipitate (23, 24). The plasma triacylglycerol concentration was measured by enzymatic spectrophotometry with the use of ammonium ions and acetyl acetone (25). LDL-cholesterol concentrations were calculated with the Friedewald formula (26). The serum glucose concentration was measured by enzymatic spectrophotometry analysis with the use of the procedure by Barthelmai and Czok (27).

Examination and interview

A trained nurse practitioner obtained heights and weights from the study subjects. Heights were measured with a tape measure that was pasted on the wall, and the subjects were weighed on a portable bathroom scale while they wore indoor clothing and no shoes. Body mass index (BMI) was calculated as weight (in kg)/height² (in m). The nurse practitioner measured each subject's blood pressure and obtained a medical history and detailed information on medication and nutrient supplement use. Additional information on demographic characteristics, health practices, and eating habits, such as sex, race, marital status, educational attainment, living arrangement, exercise, beverage and alcohol consumption, and tobacco use, was obtained.

Outcome measures

We defined metabolic risk factors as follows: 1) triacylglycerol concentrations ≥ 150 mg/dL, 2) HDL cholesterol < 40 mg/dL in men and < 50 mg/dL in women, and 3) blood pressure $\geq 130/85$ mm Hg or receiving blood pressure medication. We used the revised lower criterion for fasting glucose of 100 mg/dL rather than 110 mg/dL (28). Because waist circumference was not available in the present study, we used a BMI ≥ 31 for men and ≥ 27 for women to capture abdominal adiposity, with a basis on corresponding waist circumference thresholds in a representative population (29). The metabolic syndrome was defined as having ≥ 3 of the 5 metabolic risk factors.

Vital status

The vital status of the subjects as of October 1995 was identified. This represents a 12–15 y follow-up. The mortality of the subjects was determined by examining the annual index of deaths that occurred in Massachusetts from 1981 to October 1995. Death certificates were obtained to confirm the match. The National Death Index, a central computerized index of the death certificates filed in the vital statistics office of each state of the United States, was used to search for deaths that may have occurred outside Massachusetts. The death certificates of all the names that appeared to match or closely match the study subjects were obtained from the vital statistics office of every state where the deaths may have occurred to confirm the match. The date of death and the immediate, underlying, and contributing causes of

death were abstracted from the death certificates and coded according to the rules of the ninth revision of the International Classification of Diseases (30). A study subject who was not ascertained as dead was assumed to be alive at the end of the follow-up study.

Statistical analysis

SAS statistical software version 8.1 was used for all statistical analysis (SAS Institute, Cary, NC). For most sets of analyses, we categorized the subjects by quartiles of mean whole- and refined-grain intakes. The means or frequencies of individual characteristics were computed for each quartile of whole- and refined-grain intake. Whole grains, refined grains, and saturated fatty acids were adjusted for calorie intake, age, and sex. Analysis of covariance, using the PROC GLM procedure, was used to examine the association between quartile categories of whole and refined grains and metabolic risk factors, which included fasting glucose concentrations, triacylglycerol concentrations, BMI, diastolic and systolic blood pressure, and total, HDL-, and LDL-cholesterol concentrations. A natural logarithm transformation was applied to total and HDL-cholesterol concentrations, triacylglycerol concentrations, fasting glucose concentrations, and BMI. Two-way interactions between BMI and whole grain were tested in regression models for all the metabolic risk factor outcomes but were not found to be significant and, therefore, were not presented.

We examined the association between the metabolic syndrome and whole- and refined-grain intake using logistic regression. We also examined the association between the risk of all-cause mortality and mortality from CVD and intake of whole and refined grain using Cox proportional hazard regression. In all models, quartile categories of whole- and refined-grain intake were represented as indicator variables and the lowest quartile category was the referent group. In all the regression models, we adjusted for age, sex, race (white or other), educational attainment (grade school or less, high school, or college or graduate school), marital status (married; widowed, separated, or divorced; or single), smoking status (current smoker, or former or never smoker), exercise (≥ 3 times/wk or < 3 times/wk), BMI, calories, percentage calories from saturated fatty acids, use of antihypertensive medication (yes or no), and use of lipid-lowering medication (yes or no). In all models, tests for linear trends were measured across increasing quartiles of intake by using the median value in each quartile as the intake.

RESULTS

Characteristics of the population

The study population was composed of 179 (33%) men and 356 (67%) women with an average age of 72.1 y for men and 73.4 y for women. Forty-two percent of men and 31% of women were deceased as of October 1995. The study subjects were generally healthy and well educated, with 54% of men and 43% of women reporting some college or graduate school education. Eighty-one percent of men and 88% of women were nonsmokers, and $\approx 40\%$ of the subjects reported exercising ≥ 3 times/wk. On average, men consumed 1.6 servings of whole grain and 4.5 servings of refined grains per day, whereas women reported 1.3 servings of whole grain and 3.3 servings of refined grains per day. Bread intake, particularly whole-wheat bread, contributed 53%

of the whole grain to the diet, followed by ready-to-eat cold breakfast cereal at 19%, and hot breakfast cereal at 15%. Only $\approx 16\%$ of men and 7% of women reported consuming ≥ 3 servings of whole grains per day.

The characteristics of the subjects across quartile categories of whole- and refined-grain intake are shown in **Table 1**. Both whole- and refined-grain intakes were positively associated with calorie intake. The subjects with a higher intake of whole grains had a lower BMI, were less likely to smoke, and, although marginally statistically significant, were less likely to consume alcohol and more likely to exercise. In contrast, refined-grain intake was only marginally associated with higher alcohol intake but with no other lifestyle characteristics.

Metabolic risk factors and intake of whole and refined grains

Fasting glucose concentrations and BMI decreased across increasing quartile categories of whole-grain intake (P for trend = 0.01 and 0.03, respectively), even after adjustment for several demographic and lifestyle factors (**Table 2**). In contrast, a higher intake of refined-grain foods was associated with a higher fasting glucose concentration (P for trend = 0.04) and a higher systolic blood pressure (P for trend = 0.05; **Table 2**). A trend toward lower HDL cholesterol was also seen with higher refined-grain intake, although this trend was only marginally significant (P for trend = 0.07).

The metabolic syndrome and intake of whole and refined grains

The overall prevalence of the metabolic syndrome in this population was 40%. Compared with the subjects in the lowest quartile of whole-grain intake, the subjects who consumed more whole grains were at a significantly lower risk of having the metabolic syndrome, even after control for several risk factors (P for trend = 0.005; **Table 2**). Additionally, there was a significant trend increase in the risk of the metabolic syndrome with an increase in the intake of refined grains ($P < 0.01$). Compared with the lowest intake quartile of refined grains, the subjects who were in the highest quartile of refined-grain intake were at a significantly higher risk of the metabolic syndrome, even after control for several risk factors [odds ratio (OR):2.16; 95% CI: 1.20, 3.87].

Mortality and intake of whole and refined grains

CVD was the cause of death in 89 subjects. A significant inverse trend was observed between whole-grain intake and mortality from CVD, even after control for demographic and lifestyle factors (P for trend = 0.04). The risk of CVD death for the subjects in the highest quartile of whole-grain intake was significantly lower than for those in the lowest quartile of whole-grain intake [relative risk (RR): 0.48; CI: 0.25, 0.96] (**Figure 1**). No significant associations were found between intake of whole grain and all cause mortality (P for trend = 0.65; data not shown). Compared with the lowest quartile of whole-grain intake, RRs (95% CIs) for quartiles 2, 3, and 4, were 1.08 (0.71, 1.66), 1.24(0.83, 1.86), and 0.82 (0.52, 1.28), respectively. No significant associations were found between intakes of refined grains and all cause and CVD mortalities (P for trend = 0.69 and 0.41, respectively; data not shown).

TABLE 1

Characteristics of subjects by quartile (Q) of whole- and refined-grain intake

Characteristics	Grain intake				P for trend ¹
	Q1	Q2	Q3	Q4	
Whole grain					
<i>n</i>	135	132	135	133	
Quartile range (servings/day)	≤0.56	0.57–1.14	1.15–1.94	>1.94	
Median whole-grain intake (servings/d) ²	0.31	0.86	1.49	2.90	0.001
Median refined-grain intake (servings/d) ²	4.5	4.0	3.7	2.7	0.001
Age (y)	72.2 ± 7.7 ³	72.3 ± 7.2	72.8 ± 8.0	73.4 ± 7.1	0.15
Women (%)	69	67	71	59	0.14
White (%)	96	94	96	96	0.66
Less than a high school education (%)	59	52	46	54	0.27
BMI (kg/m ²)	27.1 ± 4.3	26.2 ± 4.0	25.8 ± 4.3	25.8 ± 5.9	0.04
Smokers (%)	23	12	13	9	0.003
Alcohol drinkers (%) ⁴	49	44	39	38	0.06
Regular exercise (%) ⁵	35	41	45	44	0.08
Energy intake (kcal)	1624 ± 385	1589 ± 471	1627 ± 456	1848 ± 488	0.001
Saturated fatty acid (% of energy) ²	12.4 ± 3.6	12.2 ± 3.4	11.6 ± 3.2	11.6 ± 3.3	0.03
Metabolic syndrome (%) ⁶	53	41	33	33	0.001
Refined grain					
<i>n</i>	133	134	136	132	
Quartile range (servings/d)	≤2.21	2.22–3.46	3.47–4.76	>4.76	
Median refined-grain intake (servings/d) ²	1.6	2.9	4.1	6.1	0.001
Median whole-grain intake (servings/d) ²	2.15	1.68	1.07	0.78	0.001
Age (y)	72.3 ± 7.4	73.0 ± 7.0	72.8 ± 7.2	72.6 ± 8.4	0.87
Women (%)	77	78	65	45	0.001
White (%)	92	95	96	98	0.04
Less than a high school education (%)	55	54	56	47	0.32
BMI (kg/m ²)	26.2 ± 4.3	26.2 ± 6.0	26.1 ± 4.6	26.5 ± 3.4	0.63
Smokers (%)	16	17	13	11	0.19
Alcohol drinkers (%) ⁴	41	40	38	53	0.06
Regular exercise (%) ⁵	30	40	42	43	0.54
Energy intake (kcal)	1445 ± 383	1513 ± 351	1733 ± 422	1997 ± 473	0.001
Saturated fatty acid (% of energy) ²	12.2 ± 3.9	12.3 ± 3.4	11.9 ± 3.2	11.5 ± 3.0	0.09
Metabolic syndrome (%) ⁶	36	38	42	44	0.15

¹ For the continuous variables, the median value in each quartile was used as a continuous variable in a linear regression; for the categorical variables, the Mantel-Haenszel chi-square test was used.

² Controlled for energy intake, age, and sex.

³ $\bar{x} \pm SD$ (all such values).

⁴ $\geq 1-2$ drinks/wk.

⁵ Physical exercise ≥ 3 times/wk.

⁶ The metabolic syndrome was defined as having ≥ 3 of the following 5 criteria: HDL cholesterol <40 mg/dL for men or <50 mg/dL for women, fasting glucose concentration ≥ 100 mg/dL, triacylglycerol concentration ≥ 150 mg/dL, blood pressure ≥ 130 (systolic)/85 (diastolic) mm Hg or use of blood pressure medication, and BMI (in kg/m²) ≥ 31 for men or ≥ 27 for women.

DISCUSSION

In this elderly cohort of healthy men and women, a higher intake of whole-grain foods was associated with improved CVD risk factors, lower prevalence of the metabolic syndrome, and a lower incidence of CVD mortality. In contrast, intake of refined-grain products was not associated with a risk of CVD mortality but was associated with a higher prevalence of the metabolic syndrome. As far as we are aware, this is the first study to examine whole-grain intake estimated from diet records and to relate this intake to the metabolic syndrome and mortality in the same population. In addition, this is the only study that we know of that examined these relations in an exclusively older population.

We found that the subjects with a higher intake of whole-grain foods (median intake: 2.9 servings/d) had a lower prevalence of the metabolic syndrome (OR: 0.46; 95% CI: 0.27, 0.79) than did the subjects with lower whole-grain intakes (median intake: <1

serving/d). In the Framingham Offspring Cohort, middle-aged men and women who reported consuming ≥ 3 servings of whole grains/d had a 32% lower prevalence of the metabolic syndrome than did those who reported consuming less servings per day (12). Similarly, the prevalence of the metabolic syndrome was 32% lower with higher intakes of whole grains in Tehranian adults (13). In contrast, Yoo et al (31) reported no association between whole-grain intake and the prevalence of the metabolic syndrome in young adults. The evidence is less consistent for refined-grain intake, with some observational studies reporting a positive association with the metabolic syndrome (13) and others finding no relation (12, 31). In our elderly population, the prevalence of the metabolic syndrome was significantly higher in the subjects who consumed, on average, ≥ 4.7 servings of refined grains/d than in the subjects who consumed <2.2 servings/d (OR: 2.16; 95% CI: 1.20, 3.87).

TABLE 2

Association between quartile (Q) of whole- and refined-grain intakes, metabolic risk factors, and prevalence of the metabolic syndrome

Variables	Grain intake				P for trend ¹
	Q1	Q2	Q3	Q4	
Whole grain					
<i>n</i>	135	132	135	133	
Median whole-grain intake (servings/d) ²	0.31	0.86	1.49	2.90	0.001
BMI (kg/m ²)	26.4	25.5	25.3	25.2	0.03
Glucose (mg/dL)	114.9	113.1	111.5	108.5	0.01
Total cholesterol (mg/dL)	225.8	222.0	216.9	217.8	0.18
HDL cholesterol (mg/dL)	49.5	51.8	52.0	50.0	0.98
LDL cholesterol (mg/dL)	147.3	140.3	136.7	139.0	0.21
Triacylglycerol (mg/dL)	111.7	108.3	100.1	106.6	0.35
Diastolic blood pressure (mm Hg)	84.4	83.1	81.4	82.5	0.14
Systolic blood pressure (mm Hg)	148.8	148.8	145.1	147.9	0.57
Metabolic syndrome ³	1.00	0.58 (0.35, 0.97) ^{4,5}	0.41 (0.24, 0.69) ⁵	0.46 (0.27, 0.79) ⁵	0.005
Refined grain					
<i>n</i>	133	134	136	132	
Median refined-grain intake (servings/d) ²	1.6	2.9	4.1	6.1	0.001
BMI (kg/m ²)	25.4	25.4	25.5	26.2	0.16
Glucose (mg/dL)	109.6	111.7	112.6	115.3	0.04
Total cholesterol (mg/dL)	222.2	220.1	221.5	219.8	0.78
HDL cholesterol (mg/dL)	53.5	49.1	50.7	49.3	0.07
LDL cholesterol (mg/dL)	140.8	141.9	139.7	142.3	0.91
Triacylglycerol (mg/dL)	103.0	108.8	108.6	108.2	0.47
Diastolic blood pressure (mm Hg)	84.0	82.9	81.2	83.5	0.51
Systolic blood pressure (mm Hg)	147.4	144.5	146.1	152.8	0.05
Metabolic syndrome ³	1.00	1.17 (0.69, 1.97)	1.57 (0.91, 2.68)	2.16 (1.20, 3.87) ⁵	0.01

¹ Analysis of covariance was used to examine the association between quartile categories of whole and refined grains and metabolic risk factors.

² All models were adjusted for age, sex, race, educational attainment, marital status, smoking, alcohol intake, exercise, BMI, energy intake, percentage saturated fatty acid intake and use of antihypertensive or lipid-lowering medication.

³ Logistic regression models were used to examine the association between the metabolic syndrome and whole- and refined-grain intake. Metabolic syndrome was defined as having ≥ 3 of the following 5 criteria: HDL cholesterol < 40 mg/dL for men or < 50 mg/dL for women, fasting glucose concentration ≥ 100 mg/dL, triacylglycerol concentration ≥ 150 mg/dL, blood pressure ≥ 130 (systolic)/85 (diastolic) mm Hg or use of blood pressure medication, and BMI (in kg/m²) ≥ 31 for men or ≥ 27 for women.

⁴ Odds ratios; 95% CIs in parentheses (all such values).

⁵ Significantly different from Q1, $P < 0.05$.

In the present study, whole-grain intake was inversely, whereas refined-grain intake was positively, associated with fasting glucose concentrations. This is probably due to the fact that this was an older population and, therefore, more susceptible to impaired glucose tolerance than were populations in other studies. Persons with impaired glucose tolerance are at an elevated risk of developing diabetes, and, thus, our findings corroborate the findings of prospective studies that have linked whole-grain intake to a reduction in the risk of type 2 diabetes (32). In healthy middle-aged Tehranian adults, a high whole-grain intake was associated with a 25% lower prevalence of impaired glucose tolerance (13). However, neither whole- nor refined-grain intakes were related to fasting glucose concentrations in the Framingham Offspring Cohort, perhaps because this was a younger population whose plasma glucose concentrations were more tightly regulated (33). Pereira et al (34) found that insulin sensitivity, which was measured with the euglycemic hyperinsulinemic clamp, improved after 6 wk on a whole-grain compared with a refined-grain diet, and, although not statistically significant, there was a tendency for fasting glucose concentrations to be lower with a whole-grain diet. In patients with coronary artery disease, replacement of refined white rice with whole-grain and legume powder for 12 wk significantly decreased fasting glucose

concentrations (35). Evidence from cross-sectional studies suggests that whole-grain intake is favorably associated with insulin resistance in nondiabetic persons (33, 36, 37), independent of body weight. Because measures of insulin sensitivity were not collected in the present study, we were unable to consider this as a potential mediating pathway.

Consistent with cross-sectional studies that used FFQs, we found that high whole-grain diets were associated with a lower BMI (2, 5, 33, 36, 38). In addition, longitudinal studies have reported that persons who have higher intakes of whole grains gain less weight than do persons who have low intakes of whole grains (38, 39). In addition, we observed that higher intakes of whole-grain foods were favorably associated with both total and LDL cholesterol, although the trend did not reach statistical significance. In the Framingham Offspring Cohort, whole-grain intake was also associated with lower concentrations of total and LDL cholesterol (33). Randomized clinical trials (40) and metabolic studies (41) have shown that oats and oat bran, both sources of whole grains, reduce total blood cholesterol. Thus, improved lipid profiles may be a potential mediating pathway whereby whole grains reduce CVD mortality. Other biologically plausible mechanisms to explain the beneficial effects of whole-grain intake on CVD

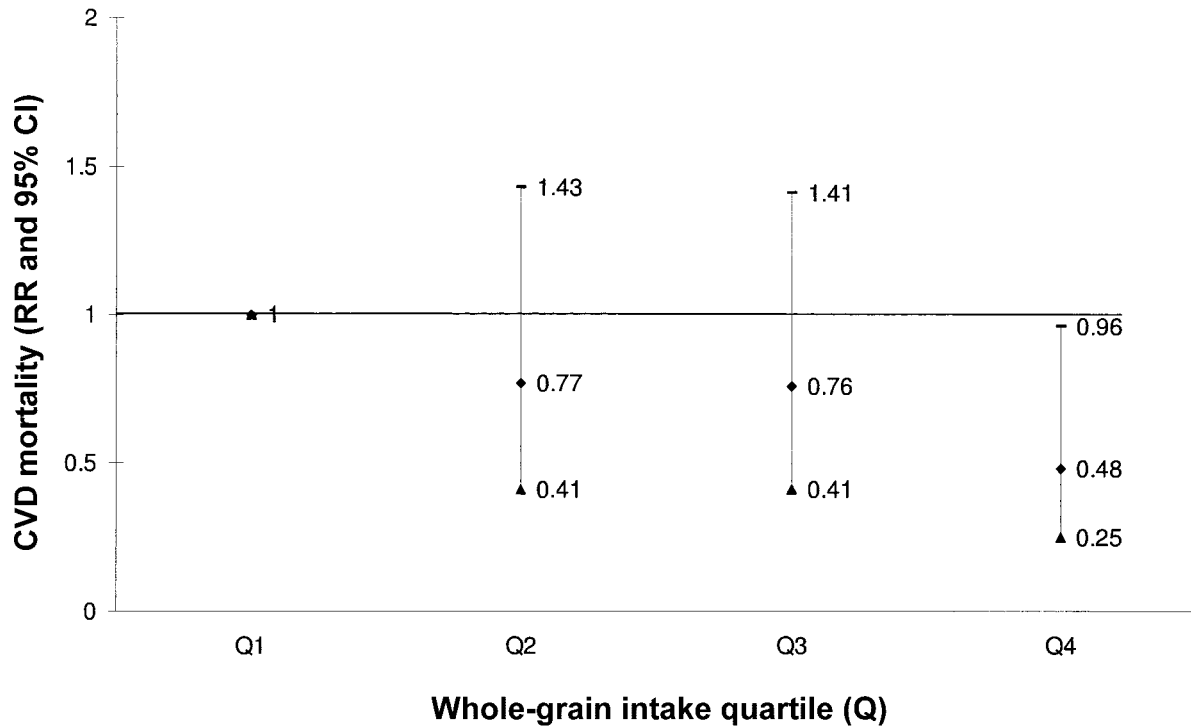


FIGURE 1. Association between whole-grain intake quartile and cardiovascular disease (CVD) mortality. Cox proportional regression analysis models were used to examine the association between mortality from CVD and whole-grain intake quartile (the referent category was the lowest quartile). The model is adjusted for age, sex, ethnicity, educational attainment, marital status, smoking, alcohol intake, exercise, BMI, energy intake, percentage saturated fatty acid intake, history of heart disease, and use of antihypertensive or lipid-lowering medication. Data are relative risks (RRs) and 95% CIs. P for trend = 0.04.

risk include improved endothelial function, fibrinolysis, and coagulation (42, 43).


We observed a significant trend in reduced CVD mortality across increasing quartile categories of whole-grain intake. This finding is consistent with findings from other studies that linked high-fiber and whole-grain foods to CVD mortality (44). In the Nurses' Health Study, a greater intake of whole-grain foods was associated with a 25% reduction of coronary artery disease and a 31% reduction of ischemic stroke, when compared with those with a lower intake of whole grains. Liu et al (45) found that CVD mortality was 20% lower in persons who consumed a whole-grain breakfast cereal daily. Recent evidence suggests that the bran component of whole-grain foods may contain the most important bioactive constituents (46). As far as we are aware, only one other prospective study, which used a FFQ to estimate whole-grain intake, observed that a higher daily intake of cereal fiber (equivalent to ≈ 2 slices of whole-grain bread per day) was associated with a lower risk of CVD in elderly persons (hazard ratio: 0.79; 95%CI: 0.62, 0.99) (47). Consistent with other studies (7, 8, 45), no relation between refined-grain intake and CVD mortality was observed in the present study.

One of the strengths of the present study was the use of diet records to differentiate whole grains from refined grains. Often, the fixed food categories that are associated with the FFQ make it difficult to separate whole and refined grains accurately for some food items, such as dark breads, which may be made with whole or refined grains. However, food diaries are able to capture this information. Consistent with observational studies that have used FFQs to capture whole-grain intake, we found that whole-grain intake was associated with a lower prevalence of the metabolic syndrome and a lower risk of CVD mortality. We cannot

conclude, however, that these observed protective associations between whole-grain intake and CVD mortality are not due to confounding by other healthy lifestyle characteristics, despite the fact that we attempted to adjust for some of the stronger lifestyle risk factors, such as engaging in regular exercise, smoking, and BMI. We also adjusted for fruit, vegetable, and dairy intakes in our models, but these variables did not change the results significantly. Also, because of the cross-sectional design, we cannot conclude that whole-grain foods causally contribute to the risk of developing the metabolic syndrome. It is possible that pre-disease conditions, such as hypertension and hypercholesterolemia, may have prompted the subjects to change their dietary habits and thereby confounded the association between whole-grain intake and CVD mortality. However, these data were collected >20 y ago, before the accumulation of evidence suggesting the health benefits of whole grains; thus, an increased consumption of whole grains in response to a diagnosis of CVD risk factors is unlikely to explain our observations. We also conducted a sensitivity analysis by examining the associations between whole and refined grains and blood pressure in persons who were not receiving blood pressure medications and between whole and refined grains and blood lipids in persons who were not receiving lipid-lowering medications. The associations and significance levels did not change substantially. Note, however, that the subjects in the present study were not a representative sample of the elderly and, therefore, these results may not be extrapolated to other populations.

The data indicated that there was an association between whole-grain intake and the metabolic syndrome, even in older adults who have different metabolic characteristics from

younger adults. In the present study, the average intake of whole-grain food was ≈ 1.6 servings/d, with the main source being whole-wheat breads (53%). Despite the fact that the present study was conducted >20 y ago, intake of whole-grain foods has not substantially changed, with the average American reportedly consuming, on average, 1 serving of whole grains/d (11).

In conclusion, we found a lower prevalence of the metabolic syndrome and a reduced risk of CVD mortality in older persons who had high whole-grain intakes. Whole-grain intake is a modifiable dietary risk factor that may lead to substantial health benefits at the population level, even in an older population. 

NRS, PFJ, NMM, XLZ, and WJ were responsible for the study concept, research design, and data analysis. NRS and NMM drafted the manuscript. PFJ was responsible for manuscript editing, advice, and consultation. All authors critically revised the article for important intellectual content. None of the authors had a conflict of interest.

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