

Whole-Grain, Cereal Fiber, Bran, and Germ Intake and the Risks of All-Cause and Cardiovascular Disease–Specific Mortality Among Women With Type 2 Diabetes Mellitus

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Background—Although whole-grain consumption has been associated with a lower risk of cardiovascular diseases (CVD) and mortality in the general population, the association of whole grain with mortality in diabetic patients remains to be determined. This study investigated whole grain and its components cereal fiber, bran, and germ in relation to all-cause and CVD-specific mortality in patients with type 2 diabetes mellitus.

Methods and Results—We followed 7822 US women with type 2 diabetes mellitus in the Nurses' Health Study. Dietary intakes and potential confounders were assessed with regularly administered questionnaires. We documented 852 all-cause deaths and 295 CVD deaths during up to 26 years of follow-up. After adjustment for age, the highest versus the lowest fifths of intakes of whole grain, cereal fiber, bran, and germ were associated with 16% to 31% lower all-cause mortality. After further adjustment for lifestyle and dietary risk factors, only the association for bran intake remained significant (P for trend=0.01). The multivariate relative risks across the fifths of bran intake were 1.0 (reference), 0.94 (0.75 to 1.18), 0.80 (0.64 to 1.01), 0.82 (0.65 to 1.04), and 0.72 (0.56 to 0.92). Similarly, bran intake was inversely associated with CVD-specific mortality (P for trend=0.04). The relative risks across the fifths of bran intake were 1.0 (reference), 0.95 (0.66 to 1.38), 0.80 (0.55 to 1.16), 0.76 (0.51 to 1.14), and 0.65 (0.43 to 0.99). Similar results were observed for added bran alone.

Conclusions—Whole-grain and bran intakes were associated with reduced all-cause and CVD-specific mortality in women with diabetes mellitus. These findings suggest a potential benefit of whole-grain intake in reducing mortality and cardiovascular risk in diabetic patients. (*Circulation*. 2010;121:2162-2168.)

Key Words: cereals ■ cardiovascular diseases ■ diabetes mellitus ■ diet ■ mortality

Several epidemiological studies have suggested that whole-grain intake may reduce the risk of type 2 diabetes mellitus,¹ cardiovascular disease (CVD),² and mortality.^{3,4} Whole-grain foods contain fiber, vitamins, minerals, phenolic compounds, phytoestrogens, and other unmeasured constituents,⁵ which may have favorable effects on health by lowering serum lipids⁶ and blood pressure,⁷ improving glucose and insulin metabolism⁸ and endothelial function, and alleviating oxidative stress⁹ and inflammation.¹⁰

Clinical Perspective on p 2168

Patients with type 2 diabetes mellitus have a 2- to 3-fold higher risk of CVD and premature mortality than the general population.¹¹ A randomized crossover trial indicated that a high-fiber diet can improve glycemic control, lower hyperinsulinemia, and improve blood lipid concentrations in diabetic

patients.¹² In addition, results from our previous study among diabetic participants suggested that high intakes of whole grain and components such as cereal fiber and bran might protect against systemic inflammation and endothelial dysfunction.¹³ We therefore hypothesized that whole-grain consumption might lower mortality, especially cardiovascular mortality, in diabetic patients.

To test this hypothesis, we prospectively examined the association between long-term intakes of whole grain, the grain subcomponents cereal fiber, bran, and germ, and the risks of all-cause and CVD-specific mortality among diabetic women from the Nurses' Health Study (NHS).

Methods

Study Population

The NHS cohort began in 1976 with the recruitment of 121 700 female registered nurses (aged 30 to 55 years) residing in 11 large

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US states. The medical history, lifestyle information, and disease diagnosis were updated every 2 years with the use of a validated questionnaire.¹⁴ The present study included 7822 women with type 2 diabetes mellitus diagnosed between 1976 and 2006. Women with diabetes mellitus diagnosed before the age of 30 years or with a history of CVD (including stroke, myocardial infarction [MI], angina, and/or coronary revascularization) or cancer reported on the 1980 questionnaire (when diet was first assessed) or before were excluded. The present study was approved by the institutional review board at Brigham and Women's Hospital, and returning the questionnaires was supposed to imply informed consent.

Confirmation of Diabetes Mellitus

Incident cases of type 2 diabetes mellitus were defined as self-reported diabetes mellitus confirmed by a validated supplementary questionnaire on symptoms, diagnostic tests, and hypoglycemic therapy. We used National Diabetes Data Group criteria¹⁵ to diagnose diabetes mellitus before the release of the American Diabetes Association criteria in 1997. The American Diabetes Association diagnostic criteria were adopted to diagnose diabetes mellitus cases during the 1998 and 2006 cycles.¹⁶ Our validation study revealed that 98% of the self-reported type 2 diabetes mellitus cases were confirmed by medical records review.¹⁷ The diagnostic criteria that we used have been reported in detail elsewhere.¹⁸

Death Ascertainment

The end points in this study included all-cause and CVD-specific mortality. The ascertainment of death has been documented in a previous study.¹⁹ Briefly, deaths were reported by next of kin or the postal system or identified through the National Death Index. We estimated previously that follow-up for deaths was >98% complete.²⁰ We obtained death certificate copies and medical records and determined causes of death according to the *International Classification of Diseases, Ninth Revision*.

Assessment of Whole-Grain, Cereal Fiber, Bran, and Germ Consumption

Semiquantitative food-frequency questionnaires were sent to the NHS participants in 1980, 1984, 1986, 1990, 1994, 1998, and 2002. On each questionnaire, participants were asked to report how often on average they had consumed foods and beverages with a specified unit or portion size during the previous year. Whole grains were defined and calculated as described previously.²¹ Briefly, the portions were converted to grams per serving, and intake of whole grains was calculated by multiplying the consumption frequency of each unit of food by the whole-grain content in grams. Intake of whole grain (in grams per day) was estimated on the basis of the dry weight of whole-grain ingredients of all grain foods (including rice, pasta, bread, and breakfast cereals). Whole-grain intake from the breakfast cereals was calculated from >250 brand name cereals according to the information from product labels or provided by breakfast cereal manufacturers. Total intake of bran and germ (in grams per day) in this study included added and naturally occurring forms from whole grain and was calculated in a similar manner. We used the residual method to energy-adjust the intakes of whole grain and fiber.²²

Statistical Analysis

We calculated cumulative averages of food and nutrient intakes from the repeated questionnaires. Nondietary covariates were updated at each biennial follow-up cycle. Person-time was calculated for each participant from the return of the questionnaire on which type 2 diabetes mellitus was first diagnosed to the occurrence of death or the end of the study period (June 1, 2006). Cox proportional hazards regression was used to examine the associations between the dietary factors and all-cause and CVD-specific mortality. Multivariable models were first adjusted for age, smoking status, body mass index

(BMI), alcohol intake, physical activity, parental history of MI, menopausal status and use of hormone therapy, and duration of diabetes mellitus. We further adjusted for cumulative averages of dietary factors including total energy and intakes of polyunsaturated fat, saturated fat, *trans* fat, magnesium, and folate. The median value of each category of dietary factor consumption was used as a continuous variable to test for linear trends. To represent the long-term intake of dietary factors and to reduce measurement error, we conducted analyses using updated dietary data by taking the average of all available dietary questionnaires.²³ To minimize residual confounding, we performed additional analyses of the association of these specific dietary factors with all-cause mortality stratified by BMI, smoking, alcohol intake, and physical activity. The SAS statistical package was used for all analyses (SAS, version 9.0 for UNIX; SAS Institute, Cary, NC). All *P* values are 2-sided.

Results

Baseline Characteristics

Compared with the lowest fifth of whole-grain intake, women in the higher fifth had a lower BMI and were less likely to smoke but were more likely to be engaged in physical activity, to use postmenopausal hormones, and to have hypercholesterolemia and hypertension. Women with higher intakes of whole grain also had higher intakes of folate, multivitamin supplements, and vitamin E supplements and lower intakes of alcohol, saturated fat, polyunsaturated fat, and *trans* fat (Table 1). The baseline characteristics across the fifths of cereal fiber, germ, and bran were similar to those for whole grains (data not shown). Correlations with whole-grain intake were 0.69 for cereal fiber, 0.78 for bran, and 0.61 for germ.

Intakes of Whole Grain, Cereal Fiber, Bran, and Germ in Relation to All-Cause Mortality

During up to 26 years of follow-up (70 102 person-years), we confirmed 852 deaths (295 deaths from CVD, including 195 deaths from coronary heart disease and 100 from stroke). In an age-adjusted analysis, we observed an inverse association between whole-grain intake and all-cause mortality (*P* for trend=0.004; Table 2). Compared with the lowest fifth of whole-grain intake, the relative risk (RR) for all-cause mortality was 0.80 (95% confidence interval [CI], 0.64 to 1.00) in the highest fifth. Further adjustment for lifestyle and dietary covariates attenuated the association to borderline significance. The multivariable RRs across the fifths of whole-grain intakes were 1.0 (reference), 1.24 (0.99 to 1.54), 0.82 (0.65 to 1.04), 0.89 (0.70 to 1.13), and 0.89 (0.69 to 1.14). Each 20-g/d increment in whole-grain intake corresponded to a 13% reduction (95% CI, 2% to 23%) in all-cause mortality after adjustment for age.

We then examined the associations between the components of whole grain (cereal fiber, bran, and germ) and all-cause mortality. All 3 components were significantly, inversely associated with risk, after adjustment for age. The association between bran intake and all-cause mortality remained significant after adjustment for lifestyle factors and other covariates (RR, 0.75; 95% CI, 0.60 to 0.95 for the highest versus the lowest fifth; *P* for trend=0.01). Further adjustment for dietary factors did not change the association materially. The RRs across the fifths of bran intakes were 1.0

Table 1. Baseline Characteristics According to Quintiles of Whole-Grain Intake Among Women With Type 2 Diabetes Mellitus (n=7822)

Variables	Whole-Grain Intake, g/d					<i>P</i> _{trend}
	Q1	Q2	Q3	Q4	Q5	
Age, y	46	47	46	47	49	
Risk factors						
BMI, kg/m ²	30.3	30.2	30.2	29.8	28.5	<0.01
Current smokers, %	21.3	16.9	11.6	9.0	10.6	<0.01
History of hypertension, %	41.5	41.9	49.1	50.0	46.0	<0.01
History of hypercholesterolemia %	34.2	31.7	42.9	45.3	45.1	<0.01
Parental history of MI, %	22.6	21.2	23.6	21.4	24.1	0.23
Postmenopausal hormone use, %	14.1	14.4	22.9	22.5	24.7	<0.01
Aspirin use, %	14.9	15.5	15.4	18.2	18.4	0.015
Physical activity, h/wk	1.95	2.17	2.39	2.50	2.74	<0.01
Alcohol, g/d	5.5	3.8	3.5	3.1	2.8	<0.01
Dietary daily intake						
Saturated fat, % energy	14.3	14.2	13.7	13.2	12.4	<0.01
Polyunsaturated fat, % energy	5.8	5.7	5.8	5.7	5.5	<0.01
<i>Trans</i> fat, % energy	2.1	2.1	2.0	1.9	1.8	<0.01
Folate, μg/d	341.3	364.0	386.6	408.8	440.8	<0.01
Glycemic load	100.0	100.8	101.9	103.3	99.2	0.61
Supplements						
Multivitamins, %	34.1	35.2	39.5	46.0	50.0	<0.01
Vitamin E, %	19.5	19.3	25.9	32.1	35.5	<0.01

Values are means, unless indicated otherwise. Q indicates quintile.

(reference), 0.94 (0.75 to 1.18), 0.80 (0.64 to 1.01), 0.82 (0.65 to 1.04), and 0.72 (0.56 to 0.92; *P* for trend=0.01). Each 1-g/d increment in bran intake corresponded to a 2% (95% CI, 1% to 4%) reduction in all-cause mortality after adjustment for age. Significant associations were found for cereal fiber after adjustment for lifestyle and other covariates. The RRs across the fifths of cereal fiber intakes were 1.0 (reference), 1.03 (0.82 to 1.29), 0.99 (0.78 to 1.25), 0.88 (0.70 to 1.12), and 0.81 (0.64 to 1.03) (*P* for trend=0.02). Further adjustment for dietary factors weakened the association (*P* for trend=0.10). Each 1-g/d increment in cereal fiber intake corresponded to an 8% (95% CI, 4% to 11%) reduction in all-cause mortality after adjustment for age. The association between germ intake and total mortality was not significant in the multivariate models. The RRs across the fifths of germ intakes were 1.0 (reference), 1.12 (0.91 to 1.40), 0.89 (0.72 to 1.11), 0.89 (0.71 to 1.13), and 0.99 (0.78 to 1.26) (*P* for trend=0.69; Table 2). We found similar inverse associations between these dietary factors and all-cause mortality stratified by BMI (<30 versus ≥30 kg/m²), smoking (never versus past and current smoking), alcohol intake (nondrinkers versus drinkers), and physical activity (with median used as the cut point; <11.8 versus ≥11.8 metabolic equivalent hours per week) (data not shown).

Intakes of Whole Grain, Cereal Fiber, Bran, and Germ and CVD-Specific Mortality

We further examined the associations between intakes of whole grain and subcomponents and CVD-specific mortality.

In age-adjusted models, intakes of whole grain, cereal fiber, and bran were inversely associated with CVD-specific mortality. Further adjustment for lifestyle and dietary variables attenuated the associations for whole grain (the multivariable RRs and 95% CIs across the fifths of whole-grain intakes were 1.0 [reference], 1.06 [0.74 to 1.52], 0.66 [0.44 to 0.97], 0.77 [0.52 to 1.14], and 0.70 [0.46 to 1.06]; *P* for trend=0.07) and cereal fiber (the multivariable RRs and 95% CIs across the fifths of cereal fiber intakes were 1.0 [reference], 1.20 [0.81 to 1.76], 1.12 [0.75 to 1.69], 1.09 [0.71 to 1.67], and 0.89 [0.57 to 1.41]; *P* for trend=0.41). However, the association between bran intake and CVD-specific mortality remained significant in the fully adjusted model. The highest fifth of bran intake was associated with 35% lower risk of CVD-specific mortality compared with the lowest fifth (RR, 0.65; 95% CI, 0.43 to 0.99; *P* for trend=0.04) (Table 3). Germ intake was not substantially associated with CVD-specific mortality. The RRs across the fifths of germ intakes were 1.0 (reference), 0.96 (0.68 to 1.37), 0.71 (0.49 to 1.02), 0.61 (0.41 to 0.91), and 0.85 (0.58 to 1.25) in the fully adjusted model (*P* for trend=0.37).

To assess whether added bran has benefits similar to those of total bran, we further examined the association of added bran intake with all-cause and CVD-specific mortality. A large proportion (26 705 person-years) of the study population did not eat products with added bran. We defined these participants with “no intake” as the reference group and created 4 additional categories for those who did consume added bran. Compared with nonconsumers of added bran, the

Table 2. RR (95% CI) of All-Cause Mortality in Women With Diabetes Mellitus According to Cumulative Average Intakes of Whole Grain, Cereal Fiber, Bran, and Germ (g/d) (1980–2006)

Variables	RR (95% CI) According to Intakes					<i>P</i> _{trend}
	Q1	Q2	Q3	Q4	Q5	
Whole-grain intake	4.8 (<7.8)	10.5 (7.8–12.1)	14.4 (12.2–17.4)	20.6 (17.5–25.4)	32.6 (25.5–146.0)	
No. of cases	154	191	154	175	178	
Person-years	13 994	14 163	13 947	13 945	14 053	
Age-adjusted	1.00	1.18 (0.95–1.45)	0.81 (0.65–1.02)	0.83 (0.67–1.04)	0.80 (0.64–1.00)	0.004
Multivariate model 1*	1.00	1.24 (1.00–1.54)	0.84 (0.67–1.06)	0.91 (0.73–1.14)	0.89 (0.71–1.11)	0.06
Multivariate model 2†	1.00	1.24 (0.99–1.54)	0.82 (0.65–1.04)	0.89 (0.70–1.13)	0.89 (0.69–1.14)	0.11
Cereal fiber intake	1.9 (<2.57)	2.99 (2.57–3.40)	3.80 (3.41–4.22)	4.70 (4.23–5.30)	6.29 (5.31–22.50)	
No. of cases	147	176	177	176	176	
Person-years	13 956	13 949	14 079	14 084	14 035	
Age-adjusted	1.00	0.94 (0.75–1.18)	0.86 (0.68–1.07)	0.77 (0.61–0.97)	0.69 (0.54–0.87)	0.0003
Multivariate model 1*	1.00	1.03 (0.82–1.29)	0.99 (0.78–1.25)	0.88 (0.70–1.12)	0.81 (0.64–1.03)	0.02
Multivariate model 2†	1.00	1.08 (0.85–1.36)	1.06 (0.83–1.35)	0.95 (0.74–1.23)	0.86 (0.66–1.12)	0.10
Bran intake	0.8 (<1.40)	1.88 (1.40–2.50)	3.22 (2.51–4.04)	5.16 (4.05–6.85)	9.73 (6.86–68.4)	
No. of cases	164	160	177	174	177	
Person-years	14 116	14 045	14 209	13 687	14 044	
Age-adjusted	1.00	0.90 (0.72–1.12)	0.81 (0.65–1.00)	0.75 (0.60–0.94)	0.69 (0.55–0.86)	0.001
Multivariate model 1*	1.00	0.95 (0.76–1.18)	0.85 (0.68–1.05)	0.86 (0.68–1.07)	0.75 (0.60–0.95)	0.01
Multivariate model 2†	1.00	0.94 (0.75–1.18)	0.80 (0.64–1.01)	0.82 (0.65–1.04)	0.72 (0.56–0.92)	0.01
Germ intake	0.2 (<0.33)	0.46 (0.33–0.51)	0.61 (0.52–0.74)	0.9 (0.75–1.10)	1.51 (1.11–18.3)	
No. of cases	166	178	175	160	173	
Person-years	14 218	14 014	13 914	13 969	13 987	
Age-adjusted	1.00	1.10 (0.89–1.35)	0.90 (0.72–1.11)	0.80 (0.64–0.99)	0.84 (0.68–1.05)	0.03
Multivariate model 1*	1.00	1.13 (0.91–1.40)	0.92 (0.74–1.14)	0.89 (0.71–1.12)	0.95 (0.76–1.18)	0.35
Multivariate model 2†	1.00	1.12 (0.91–1.40)	0.89 (0.72–1.11)	0.89 (0.71–1.13)	0.99 (0.78–1.26)	0.69

For the intake level at each quintile (Q), values are expressed as median (range).

*Adjusted for age (5-year categories), smoking status (never, past, and current 1–14, 15–24, or ≥25 cigarettes per day), BMI (<23.0, 23.0–24.9, 25.0–27.9, 28.0–29.9, or ≥30.0 kg/m²), alcohol intake (0, 0.1–4.9, 5–14, or ≥15 g/d), physical activity (<1, 1–1.9, 2–3.9, 4–6.9, or ≥7 h/wk), parental history of MI, menopausal status and use of hormone therapy, and duration of diabetes mellitus (<5, 5–10, 11–15, or ≥15 y).

†Adjusted for covariates in model 1 plus total energy, intakes of polyunsaturated, saturated, and *trans* fat, magnesium, and folate (all in quintiles).

inverse association for added bran and all-cause mortality was similar to that observed for total bran intake after adjustment for age. Further adjustment for lifestyle and dietary factors did not attenuate the inverse association when the subjects with the highest intake of added bran were compared with nonusers (RR, 0.45; 95% CI, 0.36 to 0.57; *P* for trend <0.001). Similar results were observed for CVD-specific mortality (RR, 0.36; 95% CI, 0.24 to 0.54; *P* for trend <0.001; data not shown). We did not find associations between added germ intake and all-cause or CVD-specific mortality.

Discussion

In this prospective study of 7822 women with type 2 diabetes mellitus, we observed that intakes of whole grain, cereal fiber, and bran were inversely associated with all-cause and CVD-specific mortality during a 26-year follow-up. The association for bran intake was independent of other lifestyle and dietary factors. We did not find an association between germ intake and all-cause or CVD-specific mortality.

Several mechanisms have been suggested to underlie the protective effects of whole grain and its components on health, including reduction in serum lipids⁶ and blood pressure,⁷ improvement of glucose and insulin metabolism⁸ and endothelial function, and alleviation of oxidative stress⁹ and inflammation.¹⁰ Whole grain is composed of 3 parts: bran, germ, and endosperm. The bran and germ contain many nutrients and phytochemicals and have various potential beneficial health effects.²⁴ In agreement with our observation in participants without diabetes mellitus in the NHS cohort, bran intake was more strongly associated with reduced coronary heart disease risk than germ intake.²⁵ Bran is the major source of cereal fiber and contains important bioactive constituents.²⁶ Jacobs et al³ found that fiber from whole-grain products, but not fiber from refined grain products, was inversely associated with mortality, suggesting that the botanically linked fiber and phytochemicals in bran may confer additional health benefits beyond the effect of fiber alone. Although germ also contains micronutrients and phytochemicals, our previous study in men only found inverse associations of whole

Table 3. RR (95% CI) of CVD-Specific Mortality in Women With Diabetes Mellitus According to Cumulative Average Intakes of Whole Grain, Cereal Fiber, Bran, and Germ (1980–2006)

Variables	RR (95% CI) According to Intakes					<i>P</i> _{trend}
	Q1	Q2	Q3	Q4	Q5	
Whole-grain intake						
No. of cases	62	65	52	59	57	
Age-adjusted	1.00	1.03 (0.73–1.46)	0.70 (0.48–1.02)	0.78 (0.55–1.13)	0.71 (0.49–1.03)	0.04
Multivariate model 1*	1.00	1.10 (0.78–1.57)	0.73 (0.50–1.07)	0.88 (0.61–1.27)	0.81 (0.56–1.19)	0.21
Multivariate model 2†	1.00	1.06 (0.74–1.52)	0.66 (0.44–0.97)	0.77 (0.52–1.14)	0.70 (0.46–1.06)	0.07
Cereal fiber intake						
No. of cases	53	65	61	62	54	
Age-adjusted	1.00	0.99 (0.68–1.43)	0.88 (0.60–1.29)	0.84 (0.57–1.24)	0.69 (0.46–1.02)	0.03
Multivariate model 1*	1.00	1.08 (0.74–1.57)	1.04 (0.70–1.54)	1.00 (0.68–1.49)	0.85 (0.56–1.29)	0.31
Multivariate model 2†	1.00	1.20 (0.81–1.76)	1.12 (0.75–1.69)	1.09 (0.71–1.67)	0.89 (0.57–1.41)	0.41
Bran intake						
No. of cases	61	57	65	55	57	
Age-adjusted	1.00	0.90 (0.62–1.29)	0.83 (0.58–1.19)	0.73 (0.50–1.06)	0.69 (0.47–1.00)	0.04
Multivariate model 1*	1.00	0.98 (0.68–1.42)	0.88 (0.62–1.27)	0.86 (0.58–1.25)	0.78 (0.53–1.15)	0.18
Multivariate model 2†	1.00	0.95 (0.66–1.38)	0.80 (0.55–1.16)	0.76 (0.51–1.14)	0.65 (0.43–0.99)	0.04
Germ intake						
No. of cases	69	62	59	44	61	
Age-adjusted	1.00	0.96 (0.68–1.35)	0.76 (0.54–1.08)	0.59 (0.41–0.87)	0.80 (0.56–1.13)	0.13
Multivariate model 1*	1.00	0.98 (0.69–1.39)	0.77 (0.54–1.11)	0.66 (0.45–0.97)	0.91 (0.64–1.31)	0.50
Multivariate model 2†	1.00	0.96 (0.68–1.37)	0.71 (0.49–1.02)	0.61 (0.41–0.91)	0.85 (0.58–1.25)	0.37

Q indicates quintile.

*Adjusted for age (5-year categories), smoking status (never, past, and current 1–14, 15–24, or ≥25 cigarettes per day), BMI (<23.0, 23.0–24.9, 25.0–27.9, 28.0–29.9, or ≥30.0 kg/m²), alcohol intake (0, 0.1–4.9, 5–14, or ≥15 g/d), physical activity (<1, 1–1.9, 2–3.9, 4–6.9, or ≥7 h/wk), parental history of MI, menopausal status and use of hormone therapy, and duration of diabetes mellitus (<5, 5–10, 11–15, or ≥15 y).

†Adjusted for covariates in model 1 plus total energy, intakes of polyunsaturated, saturated, and *trans* fat, magnesium, and folate (all in quintiles).

grain and bran, but not germ, with coronary heart disease,²⁷ consistent with our results.

Our findings are also consistent with findings from clinic trials that whole-grain and bran consumption may improve the metabolic profiles in diabetic patients. In a randomized controlled trial conducted in hyperinsulinemic adults, consumption of whole grains for 6 weeks improved insulin sensitivity compared with consumption of refined grains.²⁸ Another clinical trial found that consumption of whole grain and legume powder can reduce fasting glucose levels in diabetic patients with coronary artery disease compared with consumption of refined rice.²⁹ Results of intervention studies of wheat bran are inconsistent. Two studies found that there were beneficial effects on glucose tolerance in individuals with or without glucose intolerance,^{30,31} whereas another study including 23 diabetic patients who completed two 3-month phases of diet intervention did not find favorable effects of wheat bran on glycemic control.³² Nevertheless, oat bran can improve glycemic and insulinemic responses and beneficially influence plasma lipid levels in diabetic patients.³³ In the present study, although we did not analyze different sources of bran, both total and added bran intakes were inversely associated with all-cause or CVD-specific mortality in diabetic patients. However, additional investigations relating difference sources of bran to beneficial effects on diabetic patients are warranted in future studies.

Several cohort studies found that the whole-grain components magnesium and folate were inversely associated with risk of all-cause mortality and CVD-specific mortality.^{34,35} However, in our study, magnesium and folate did not fully explain the inverse associations between whole grain and subcomponents and mortality, suggesting that other components of whole grain may play important roles.

Our study had several strengths. First, we analyzed data collected in a prospective cohort study. This minimized recall bias and reverse causation. Second, we used cumulative average intakes of multiple repeated measurements of dietary intakes from updated dietary questionnaires reflecting long-term dietary intakes and therefore reduced measurement error.²³ Several potential limitations also need to be considered. Higher intake of whole grain is part of a cluster of healthier dietary and lifestyle habits (eg, less smoking, more physical activity, and lower BMI). Although we adjusted for the lifestyle and dietary factors known to be associated with CVD and mortality, the potential of uncontrolled and unmeasured confounders might still remain. The observed associations may be confounded by the correlation between whole-grain intake and other greater health-conscious behaviors and better glycemic control through unknown means. In addition, although we used cumulative average intakes of multiple

repeated measurements reflecting long-term diet, the measurement error of dietary intake assessment is unavoidable. Despite a relatively large sample size, our study was still underpowered to detect modest associations. For all-cause mortality, we had 80% power to detect the association with $RR \leq 0.72$ (or $RR \geq 1.38$; $\alpha=0.05$); for CVD-specific mortality, we could detect $RR \leq 0.59$ (or $RR \geq 1.69$) with 80% power and $\alpha=0.05$. Thus, the nonsignificant associations with whole grains and cereal fiber may be due to the limited power of our study. Finally, because the present study was conducted in white women, the associations need to be examined in men and other ethnic groups.

In summary, we found that intakes of whole grain, especially its subcomponent bran, were inversely associated with all-cause and CVD-specific mortality among women with type 2 diabetes mellitus. Our findings suggest that low whole-grain intake may be considered an important modifiable risk factor for decreasing mortality and cardiovascular risk in diabetic patients.

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Disclosures

None.

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CLINICAL PERSPECTIVE

Although whole grain consumption has been associated with a lower risk of cardiovascular disease incidence and mortality in the general population, little is known about the effect of whole grain and its components on cardiovascular risk and mortality in diabetic patients. In this prospective study, we followed 7822 US women with type 2 diabetes mellitus for up to 26 years to investigate intakes of whole grain and its components cereal fiber, bran, and germ in relation to all-cause and cardiovascular disease-specific mortality. Our results indicated that intakes of whole grain, especially its subcomponent bran, were inversely associated with all-cause and cardiovascular disease-specific mortality among women with type 2 diabetes mellitus. Low whole-grain intake may be considered an important modifiable risk factor for decreasing mortality and cardiovascular risk in persons with diabetes mellitus.



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