Dietary Fiber Intake and Glycemic Index and Incidence of Diabetes in African-American and White Adults

The ARIC Study

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OBJECTIVE — To determine the association of dietary fiber and glycemic index with incident type 2 diabetes in African-Americans and whites.

RESEARCH DESIGN AND METHODS — We studied 12,251 adults aged 45–64 years and free of diabetes at baseline (1987–1989). A total of 1,447 cases of diabetes were reported between baseline and 9 years of follow-up. Diabetes status was determined by fasting glucose level ≥126 mg/dl (7.0 mmol/l), nonfasting glucose level ≥200 mg/dl (11.1 mmol/l), self-report of physician diagnosis, or use of diabetes medication. Usual dietary intake over the previous year was obtained at baseline using a 66-item food-frequency questionnaire. Nutrients were energy-adjusted using the residuals method. Proportional hazard regression analysis was used to examine dietary fiber intake and glycemic index as predictors of type 2 diabetes in both ethnic groups.

RESULTS — After adjustment for age, BMI, education, smoking status, physical activity, sex, and field center, there were no statistically significant associations of intake of total dietary fiber, fruit fiber, legume fiber, glycemic index, or glycemic load with incident diabetes. The hazard ratio for the fifth compared with the first quintile of cereal fiber was 0.75 (95% CI 0.60–0.92) in whites and 0.86 (0.65–1.15) in African-Americans.

CONCLUSIONS — This finding supports a protective role for cereal fiber in the development of diabetes in whites. More studies are needed to determine the role of dietary fiber and glycemic index in diabetes in African-Americans.

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The incidence of diabetes has been increasing, and this epidemic may continue to escalate over the next decade, especially in minorities. For >30 years, researchers have been interested in potential beneficial effects of dietary fiber intake among individuals with diabetes (1,2). In that time, many clinical studies have investigated the effect of high-fiber diets in persons with diabetes (3). More recently, the role of dietary fiber in the prevention of diabetes has received attention (4–9). Fiber, particularly soluble fiber, has repeatedly been shown to decrease postprandial glucose and insulin concentrations both in individuals with diabetes and in those without diabetes (3).

Studies that have examined the effects of total fiber or types of fiber on self-reported incidence of diabetes (4–6,8,9) have shown mixed results. No association between total dietary fiber intake and diabetes risk was found in the Health Professionals' Follow-Up Study (6) or the Seven Countries Study (Finnish and Dutch cohorts) (4). In contrast, a significant and inverse association was found between total dietary fiber intake and diabetes in both the Iowa Women's Health Study (8) and the Nurses' Health Study (5). Inverse associations between diabetes risk and cereal fiber intake were reported from three large prospective studies: the Nurses' Health Study (5,9), the Health Professionals' Follow-Up Study (6), and the Iowa Women's Health Study (8). Associations between other types of fiber intake and diabetes risk were also examined in these studies (5,6,8), but no significant associations were found.

It is well established that various sources of carbohydrate intake produce different glycemic responses (10). The glycemic index and glycemic load have been proposed as methods of ranking foods on the basis of the incremental blood glucose response they produce for a given amount of carbohydrate (11,12). The glycemic index, a relative measure of glycemic response to a given amount of carbohydrate, represents the quality of carbohydrate but not the quantity, whereas the glycemic load represents the quality as well as the quantity of carbohydrate consumed and may be interpreted as a measure of diet-induced insulin demand.

Use of the glycemic index or glycemic load as a predictor of disease risk in epidemiological studies has been controversial. One issue in this debate is the validity of these indexes calculated from dietary intakes assessed using the usual methods employed in large studies. Another issue is whether the glycemic index can be used to predict the glycemic and insulin responses to mixed meals (13). Although

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Abbreviations: ARIC, Atherosclerosis Risk in Communities.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

we recognize the limitations of this methodology, it is intriguing that significant associations between the glycemic index and/or glycemic load and diabetes have been observed, despite the imprecision of the measures. Results from two large prospective studies, the Nurses' Health Study (5,9) and the Health Professionals' Follow-Up Study (6), showed a positive association between the glycemic index and diabetes risk. However, results from the Iowa Women's Health Study (8) did not show a consistent association between the glycemic index and diabetes risk. It is clear that additional studies on the effects of glycemic index and glycemic load on the risk of developing diabetes are needed. Furthermore, no studies have examined these associations in African-Americans, a group at increased risk for diabetes.

The purpose of this study is to examine the association of various sources of dietary fiber and the glycemic index with incidence of diabetes in African-Americans and whites. Previous cohort studies of this topic assessed diabetes from self-report (5,6,8,14–16). To the best of our knowledge, this study is the first to examine associations between dietary fiber and glycemic index and new cases of diabetes using measurements of fasting glucose and the 1997 American Diabetes Association criteria (17) as well as the first to examine these associations in African-Americans.

RESEARCH DESIGN AND METHODS

Study population

The Atherosclerosis Risk in Communities (ARIC) study is a prospective, multicenter investigation of atherosclerosis and cardiovascular disease. Baseline data for ARIC were collected between 1987 and 1989 from 6,050 white women, 2,605 African-American women, 5,428 white men, and 1,606 African-American men (n = 15,689) aged 45–64 years. Participants were from four communities in the U.S.: Forsyth County, North Carolina; Jackson, Mississippi; the northwestern suburbs of Minneapolis, Minnesota; and Washington County, Maryland. The study design, sampling strategy, and examination techniques have been published (18). Cohort members were reexamined in the clinic for a maximum of four visits, which took place at approximately 3-year intervals. A total of ~80% of the cohort that remained alive at the end of the study period was examined at all four visits.

Response rates to the baseline examination were 46% in Jackson, Mississippi, and 65–67% in the other three communities. The response rates were similar in white men and women (67 and 68%, respectively) but were considerably lower in the African-American participants, particularly African-American men living in Jackson, Mississippi (42%). Differences between study participants and those who chose not to participate have been examined in detail (19).

Exclusions

Ethnicity was assessed by self-identification of a single choice from a checklist. For these analyses, participants of ethnicity other than African-American or white were excluded (n = 48). Also, African-Americans from Minnesota and Maryland were excluded because they were too few to support sex- and field center–specific modeling (n = 55). Participants with prevalent diabetes at baseline (n = 1,863) were excluded. In addition, participants who attended an examination but were missing one of the variables used to determine diabetes status were excluded (n = 147 at baseline and n = 819 at following visits). Participants were classified as having diabetes if they had fasting glucose level ≥126 mg/dl (7.0 mmol/l) or nonfasting glucose level ≥200 mg/dl (11.1 mmol/l), reported that a physician had told them they had diabetes, or reported taking medication for diabetes within 2 weeks preceding their examination. National data have shown that among adults between 30 and 74 years of age with diagnosed diabetes, most cases are type 2 diabetes; only 7.4% of cases were type 1 diabetes (20). Therefore, it is likely that most cases identified will be type 2 diabetes, and they will be referred to as such herein. To eliminate implausible nutrient intake values, men who consumed <697 or >3,763 kcal/day and women who consumed <596 or >3,125 kcal/day (the highest and lowest 1% of the sex-specific total energy intake distributions) were excluded (n = 259). Participants for whom covariate information was missing were also excluded (n = 64). The analysis consisted of the remaining 12,251 participants (9,529 whites and 2,722 African-Americans).

Dietary assessment

The usual dietary intake of the participants over the preceding year was assessed using an interviewer-administered 66-item semiquantitative food-frequency questionnaire. The questionnaire was a modified version of the 61-item instrument designed and validated by Willett et al. (21).

The average dietary glycemic load for each participant was calculated by summing the products of the carbohydrate content per serving for each food times the average number of servings of that food per day times the glycemic index for that food (12). Glycemic index was computed for each subject by dividing the glycemic load by the total carbohydrate intake per day (12). The database used white bread as the standard for glycemic index. White bread has been recommended over a glucose solution because bread is more palatable and the excessive sweetness and the osmotic effect of glucose solutions could delay gastric emptying (22).

Statistical analysis

Time to development of diabetes was evaluated for dietary fiber and glycemic index using survival analysis. For those participants who were not diagnosed with incident diabetes, person-time was calculated from baseline to the date of the last visit. For those participants in whom incident diabetes was diagnosed, person-time was calculated as the sum of the known disease-free period plus half of the interval between the date of the last visit in which the participant did not have diabetes and the date of the visit in which the diagnosis was made.

All analyses were conducted with and without adjustment for total energy using the residuals method (23). Results were not substantially different, and energy-adjusted results are shown. Cox proportional hazard regression analysis was used to examine the explanatory capability of dietary fiber intake, glycemic index, and glycemic load as predictors of diabetes. Three-way interactions between sex, ethnicity, and each nutritional variable were tested, and none were significant. Separate two-way interactions between each nutritional variable and sex and between each nutritional variable and ethnicity were also not significant. Even though the interactions with ethnicity were not statistically significant, we conducted analy-

Table 1—*Characteristics of baseline diabetes-free population by quintiles of total dietary fiber, ARIC 1987–1989*

	Total dietary fiber quintiles (mean)									
	Whites					African-Americans				
	1 (11.2)	2 (13.4)	3 (16.1)	4 (19.3)	5 (27.5)	1 (10.2)	2 (11.6)	3 (14.3)	4 (18.1)	5 (26.1)
Women	34.3	51.8	56.9	61.4	63.3	47.2	58.4	65.8	71.4	71.0
Incidence of diabetes	11.2	10.5	10.3	9.6	9.4	18.1	18.3	15.4	17.0	19.1
Age (years)	53.1 ± 5.5	53.7 ± 5.5	54.1 ± 5.6	54.6 ± 5.8	55.2 ± 5.6	52.4 ± 5.7	52.8 ± 5.7	53.3 ± 5.8	53.3 ± 5.8	53.6 ± 5.8
BMI (kg/m^2)	26.8 ± 4.4	26.7 ± 4.5	26.7 ± 4.6	26.5 ± 4.5	26.4 ± 4.6	28.7 ± 6.1	28.6 ± 5.8	29.5 ± 5.7	29.6 ± 6.3	29.3 ± 6.1
Smoking status										
Current	38.1	27.1	20.8	17.7	14.5	42.1	33.5	28.9	24.0	20.4
Former	34.4	35.6	35.7	36.5	35.9	23.1	22.7	21.8	22.7	25.2
Never	27.6	37.2	43.6	45.8	49.5	34.9	43.8	49.3	53.2	54.4
Physical activity										
Low	43.2	37.8	33.1	30.0	27.2	60.7	63.9	57.3	56.8	44.1
Medium	30.3	30.4	32.4	33.9	31.9	29.2	23.1	27.3	26.3	30.3
High	26.4	31.8	34.5	36.1	40.9	10.2	13.0	15.4	16.9	25.6
Education										
Less than high school	17.2	14.8	13.9	13.7	15.5	46.7	41.9	38.5	34.7	25.6
High school	37.0	37.2	36.7	36.6	34.3	22.5	19.6	21.4	20.8	23.5
Vocational school	10.0	9.0	9.2	8.4	9.6	6.5	7.5	7.1	7.2	7.5
College	28.1	30.3	30.4	31.6	29.1	13.8	19.0	20.0	19.7	21.7
Graduate/professional school	7.7	8.7	9.8	9.8	11.5	10.5	11.9	13.0	17.6	21.7
Dietary factors										
Total energy intake (kcal/day)	1,796 ± 638	1,531 ± 549	1,528 ± 536	1,562 ± 511	1,708 ± 538	1,780 ± 611	1,456 ± 519	1,485 ± 536	1,551 ± 536	1,740 ± 590
Cereal fiber (g/day)	2.7 ± 1.7	3.0 ± 1.6	3.5 ± 1.9	3.9 ± 2.1	5.1 ± 3.6	2.8 ± 1.6	2.8 ± 1.5	2.9 ± 1.6	3.3 ± 1.8	4.0 ± 2.6
Fruit fiber (g/day)	4.5 ± 1.4	5.8 ± 1.5	6.9 ± 1.9	8.1 ± 2.3	10.9 ± 4.5	4.1 ± 1.2	5.2 ± 1.4	6.4 ± 1.8	7.8 ± 2.4	11.2 ± 5.9
Legume fiber (g/day)	0.9 ± 0.9	1.0 ± 1.0	1.1 ± 1.1	1.4 ± 1.3	2.1 ± 2.2	0.8 ± 0.8	0.9 ± 0.8	1.1 ± 0.9	1.4 ± 1.4	1.8 ± 1.7
Glycemic index	77.0 ± 5.7	77.2 ± 5.4	77.1 ± 5.1	76.7 ± 4.9	76.0 ± 5.0	82.0 ± 4.8	81.5 ± 5.1	80.2 ± 5.1	78.6 ± 5.0	76.5 ± 5.2
Glycemic load	144 ± 74	130 ± 57	136 ± 54	148 ± 52	172 ± 59	165 ± 77	135 ± 57	141 ± 57	151 ± 57	177 ± 65

Data are means ± SD or %.

ses stratified by ethnic group because of our interest in diabetes in African-Americans and because analyses of associations between dietary fiber intake and glycemic index and diabetes in this group are rare.

RESULTS — In the 12,251 participants free of diabetes at baseline, diabetes was diagnosed in 1,447 individuals over an average follow-up period of 9 years. The incidence of diabetes was higher in African-Americans (17.5%) than in whites (10.2%). The participant characteristics by quintiles of total dietary fiber for whites and African-Americans are shown in Table 1. Among whites, but not African-Americans, incidence of diabetes decreases with increasing total dietary fiber. Those with higher total dietary fiber intake were more likely to be women, engage in more physical activity, and have more education and were less likely to be current smokers.

The participant characteristics by quintiles of glycemic index for whites and African-Americans are shown in Table 2. There was no association between diabetes incidence and glycemic index in whites or African-Americans. Those in the highest quintiles of the glycemic index were less likely to be women and were more likely to engage in less physical activity, to have less education, and to be current smokers.

We examined associations between dietary fiber and glycemic index and incident type 2 diabetes using dietary variables as continuous variables and in quintiles. The analysis of the dietary variables in the continuous form tested whether a straight line describing the data had a nonzero slope. The results obtained from these two types of models generally agreed, and all dietary variables examined that were found to have a statistically significant association in the categorical analysis were also found to have a statistically significant association in the analysis that examined dietary variables in the continuous form. We also tested models that included a quadratic term for each nutrient. None was statistically significant, and those results are not shown here.

Results from the analysis of the dietary variables in the continuous form are shown in Table 3. We initially adjusted for age, BMI, sex, and field center. Additional models adjusted for education (less

Table 2—*Characteristics of baseline diabetes-free population by quintiles of glycemic index, ARIC 1987–1989.*

	Glycemic index quintiles (mean)									
	Whites					African-Americans				
	1 (69.1)	2 (74.5)	3 (77.2)	4 (79.7)	5 (83.4)	1 (71.7)	2 (77.6)	3 (80.2)	4 (82.6)	5 (86.6)
Women	63.7	55.9	51.6	47.2	49.3	76.6	66.2	61.0	57.9	52.3
Incidence of diabetes	10.0	9.9	9.2	10.4	11.4	18.6	17.4	16.6	18.4	16.7
Age (years)	54.1 ± 5.6	54.3 ± 5.7	54.0 ± 5.6	54.2 ± 5.8	54.2 ± 5.7	52.4 ± 5.6	52.8 ± 5.7	53.1 ± 5.8	53.6 ± 5.7	53.5 ± 5.9
BMI (kg/m^2)	26.7 ± 4.5	26.7 ± 4.5	26.5 ± 4.5	26.6 ± 4.5	26.6 ± 4.7	29.8 ± 6.2	29.0 ± 5.8	28.9 ± 6.0	29.0 ± 5.7	28.9 ± 6.3
Smoking status										
Current	24.8	21.4	24.1	23.2	24.7	28.7	24.8	29.8	30.0	35.6
Former	35.9	36.8	35.3	36.1	34.0	21.5	21.6	23.6	24.1	24.6
Never	39.3	41.8	40.7	40.6	41.2	49.8	53.6	46.6	46.0	39.8
Physical activity										
Low	30.8	33.6	32.6	35.9	38.6	47.6	56.3	58.6	58.5	61.8
Medium	31.4	31.9	31.3	33.7	30.7	29.8	26.4	25.0	28.1	26.8
High	37.8	34.6	36.2	30.4	30.8	22.6	17.2	16.4	13.4	11.4
Education										
Less than High school	13.5	12.7	14.6	16.1	18.1	28.7	29.5	34.6	40.6	54.3
High school	33.5	34.2	36.5	37.4	40.2	22.1	21.8	19.9	21.0	23.3
Vocational school	9.6	9.1	8.8	8.6	10.0	8.3	7.7	7.7	6.4	5.5
College	32.8	33.0	30.0	29.1	24.5	21.0	22.8	20.3	19.8	10.3
Graduate/professional school	10.5	10.9	10.0	8.8	7.3	20.0	18.2	17.5	12.1	6.6
Dietary factors										
Total energy intake (kcal/day)	1,566 ± 574	1,647 ± 575	1,658 ± 565	1,673 ± 572	1,581 ± 538	1,606 ± 624	1,654 ± 609	1,674 ± 583	1,587 ± 530	1,483 ± 500
Total dietary fiber (g/day)	18.2 ± 9.4	18.3 ± 8.3	17.8 ± 7.3	17.3 ± 7.1	15.9 ± 6.8	20.2 ± 10.6	17.8 ± 7.8	16.3 ± 6.9	14.0 ± 5.9	11.9 ± 4.8
Cereal fiber (g/day)	2.9 ± 2.3	3.5 ± 2.3	3.8 ± 2.2	4.0 ± 2.6	4.1 ± 2.6	2.7 ± 1.8	3.2 ± 1.9	3.3 ± 2.0	3.3 ± 2.0	3.4 ± 1.7
Fruit fiber (g/day)	8.6 ± 4.6	7.9 ± 3.4	7.2 ± 2.9	6.6 ± 2.7	5.9 ± 2.2	9.6 ± 6.1	7.8 ± 3.5	6.7 ± 2.8	5.9 ± 2.3	4.9 ± 1.6
Legume fiber (g/day)	1.4 ± 1.7	1.5 ± 1.6	1.4 ± 1.4	1.3 ± 1.3	1.0 ± 1.1	1.5 ± 1.6	1.3 ± 1.4	1.3 ± 1.2	1.0 ± 1.0	0.8 ± 0.8
Glycemic load	122 ± 53	141 ± 56	150 ± 59	159 ± 63	160 ± 66	136 ± 64	156 ± 64	164 ± 66	161 ± 63	151 ± 63

Data are means ± SD or %.

than high school, high school graduation, vocational school, college graduation, or graduate/professional school), smoking status (never, former, or current), and physical activity (classified as tertiles). These further analyses yielded similar results, although the hazard ratios were somewhat attenuated for most of the dietary factors.

As shown in Table 3, total dietary fiber intake tended to be inversely associated with incident diabetes, and the trends were in inconsistent directions for fruit fiber and legume fiber. Cereal fiber was inversely associated with risk of diabetes in both ethnicities but statistically significant only in whites (hazard ratio 0.956, 95% CI 0.925–0.987 for 1 g/day cereal fiber). In whites, the hazard ratio for diabetes was 0.75 (0.60–0.92) in the fifth quintile of cereal fiber intake compared with the first quintile. In African-Americans, the same hazard ratio was 0.86 (0.65–1.15). The addition of cereal fiber to the models examining associations between dietary fiber, fruit fiber, and legume fiber resulted in findings almost identical to those that were unadjusted and were not statistically significant.

Glycemic index and glycemic load were also not significantly associated with diabetes risk. Further adjustment of the full model for cereal fiber intake produced results that were borderline significant for glycemic load. In the latter model, glycemic load was positively associated with risk of diabetes in whites ($P = 0.07$). The hazard ratio associated with a 1-SD increase in glycemic load was 1.130 (1.000–1.276). Examination of the quintiles did not show a systematic increase in risk with increasing glycemic load, and none of the quintiles were significantly different from the reference group. The hazard ratio for the fifth versus the first quintiles of glycemic load was 1.10 (0.90–1.39) in whites and 0.97 (0.73–1.35) in African-Americans in the fully adjusted model.

CONCLUSIONS — We did not detect an association between total dietary fiber intake and diabetes risk. Failure to detect an association may have been due to the instrument used to assess diet, i.e., a 66-item semiquantitative food-frequency questionnaire. No association between total dietary fiber and diabetes was reported in the Nurses' Health Study (14), using a 61-item semiquantitative

Table 3—*Multivariate-adjusted hazard ratios for association of incident type 2 diabetes with energy-adjusted dietary fiber intake and glycemic index by ethnicity*

	Whites		African-Americans	
Variables	Hazard ratio (95% CI)	*P*	Hazard ratio (95% CI)	*P*
Total dietary fiber (g/day)				
Model 1*	0.993 (0.981–1.012)	0.288	0.997 (0.979–1.015)	0.739
Model 2†	0.999 (0.987–1.012)	0.915	0.998 (0.980–1.017)	0.849
Cereal fiber (g/day)				
Model 1	0.947 (0.917–0.978)	0.001	0.979 (0.925–1.036)	0.460
Model 2	0.956 (0.925–0.987)	0.006	0.982 (0.927–1.039)	0.525
Fruit fiber (g/day)				
Model 1	0.994 (0.975–1.014)	0.571	1.007 (0.984–1.031)	0.538
Model 2	1.002 (0.983–1.021)	0.841	1.009 (0.985–1.033)	0.479
Legume fiber (g/day)				
Model 1	1.005 (0.957–1.056)	0.831	0.958 (0.879–1.043)	0.323
Model 2	1.007 (0.959–1.058)	0.774	0.961 (0.882–1.047)	0.366
Glycemic index				
Model 1	1.000 (0.988–1.013)	0.989	0.999 (0.982–1.015)	0.879
Model 2	0.998 (0.986–1.010)	0.745	0.998 (0.982–1.015)	0.848
Model 3‡	1.002 (0.990–1.015)	0.730	1.000 (0.982–1.017)	0.982
Glycemic load				
Model 1	1.001 (0.999–1.000)	0.499	0.999 (0.996–1.001)	0.364
Model 2	1.010 (0.999–1.003)	0.355	0.999 (0.996–1.002)	0.414
Model 3	1.002 (1.000–1.004)	0.073	0.999 (0.996–1.002)	0.472

*Model 1: adjusted for age, BMI, sex, field center (Forsyth, Jackson, Minneapolis, or Washington); †Model 2: adjusted for age, BMI, sex, field center (Forsyth, Jackson, Minneapolis, or Washington), education (less than high school, high school graduation, vocational school, college graduation, or graduate/professional school), smoking status (never, former, or current), physical activity (low, medium, or high); ‡Model 3: additionally adjusted for cereal fiber.

food-frequency questionnaire administered in 1980, or in the Health Professionals' Follow-Up Study (6), using a 131-item food-frequency questionnaire. In contrast, a significant and inverse association was found between total dietary fiber intake and diabetes in both the Iowa Women's Health Study (8), using a 127-item food-frequency questionnaire, and the Nurses' Health Study (5), using a 134-item expanded food-frequency questionnaire administered in 1986.

Several clinical studies (1,2,24,25) have documented that a high-fiber diet is beneficial for individuals with diabetes, resulting in lower fasting and postprandial plasma glucose and insulin levels, reduced insulin requirements, lower serum total and LDL cholesterol levels, and high HDL cholesterol. More than 25 years ago, Trowell (26) suggested that different sources of fiber may be differentially associated with risk of diabetes.

We found that cereal fiber intake was significantly inversely associated with risk of diabetes in whites but not in African-Americans. The lack of association among African-Americans may be due to the small sample size. Similar inverse associations between diabetes risk and cereal fiber intake were reported from three large prospective studies: the Nurses' Health Study (5,9), the Health Professionals' Follow-Up Study (6), and the Iowa Women's Health Study (8). Although clinical studies (1) have documented that legumes are notable for the low blood glucose response they produce, we found no association between legume fiber intake and diabetes risk in African-Americans or whites. The Iowa Women's Health Study (8) also found no association between legume fiber intake and diabetes risk. No association between fruit fiber intake and diabetes risk was reported in our study or in three other large prospective studies (5,6,8).

Several studies have also found inverse associations between dietary fiber or whole-grain intake and coronary heart disease (27–31). Three of these studies also examined the association between cereal fiber and coronary heart disease (29–31) and found a stronger inverse association for total dietary fiber than cereal fiber (30), a stronger association for cereal fiber than total dietary fiber (31), and similar inverse associations for cereal fiber and total dietary fiber (29). In studies examining the association between dietary fiber and risk of diabetes, the Nurses' Health Study (5), the Health Professionals' Follow-Up Study (6), and the Iowa Women's Health Study (8) found a stronger inverse association between risk of diabetes and cereal fiber than total dietary fiber. However, it is possible that cereal fiber is a marker for the type of carbohydrate that is protective against diabetes incidence while total dietary fiber is not.

Several clinical studies reported that reducing the glycemic index of the diet, with no change in macronutrient composition, results in a modest improvement in long-term blood glucose control in patients with type 1 and type 2 diabetes (32) and in normal subjects (33). Two large prospective studies, the Nurses' Health Study (5) and the Health Professionals' Follow-Up Study (6), showed positive associations between the glycemic index and diabetes risk. However, the present study as well as the Iowa Women's Health Study (8) do not support a consistent association between glycemic index or glycemic load and diabetes risk. Although analyses using glycemic load in quintiles did not detect a significant association with diabetes risk, the *P* values associated with glycemic load were borderline significant and positive when analyzed as a continuous variable and adjusted for cereal fiber. In contrast, in the Iowa Women's Health Study (8), no difference was found in the association between glycemic load and diabetes risk before or after adjustment for total dietary fiber. Two studies (5,6) have shown a joint effect of the glycemic load and cereal fiber intake. They cross-classified participants by both variables and demonstrated adverse effects of high glycemic load in combination with low cereal fiber intake (RR = 2.2).

An important limitation of this study is the use of food-frequency questionnaires to characterize dietary fiber intake and glycemic index. Although food-frequency questionnaires are useful for ranking individuals according to relative intake within a large study population, the 66-item semiquantitative food-frequency questionnaire used in the ARIC study was not specifically designed to assess dietary fiber intake and glycemic index.

Another concern is the validity of the glycemic index data for different carbohydrate sources (34). In addition, the validity of glycemic index when individual carbohydrate foods are incorporated into a mixed meal is controversial. Although some research has documented that pooled glycemic index values of individual foods can rank glucose responses to mixed meals (35,36), other studies have raised doubt about the assessment of mixed meals (37,38).

A strength of this study is that it included a large number of individuals, including African-Americans. Another strength is the accuracy of case determination of diabetes. Studies using self-report of diabetes have shown low accuracy in validation studies. In the ARIC cohort, we measured serum glucose concentrations, and this information was used in the identification of cases. We have a more accurate determination of incident cases of diabetes than studies that used self-report, and we included cases of formerly undiagnosed and perhaps less advanced disease.

The findings from this investigation, along with those of other studies (4–6,8,9), raise the interesting possibility that some types of dietary fiber and glycemic load may play important roles in determining diabetes risk. Studies with more precise assessments of both dietary intake and diabetes are needed. Also, additional studies are needed on the role of diet in the prevention of diabetes in African-Americans and other ethnic groups that are at increased risk for this disease.

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