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Dietary fiber, lung function, and chronic obstructive pulmonary disease in the Atherosclerosis Risk in Communities (ARIC) Study

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Abstract

Recent data suggest beneficial effects of fiber intake on chronic respiratory symptoms in adults that are independent of antioxidant vitamin intake, but little is known about fiber consumption in relation to lung function and chronic obstructive pulmonary disease (COPD). The authors investigated the association of fiber intake with lung function and COPD in 11,897 men and women from the Atherosclerosis Risk in Communities (ARIC) study. After controlling for potential confounders, positive associations between lung function and fiber intake from all sources as well as from cereal or fruit alone were found. Participants in the highest quintile of total fiber intake had 60.2 ml higher forced expiratory volume in 1 second (FEV_1) (*p* for trend<0.001), 55.2 ml higher forced vital capacity (FVC) (*p*=0.001), 0.4% higher FEV_1/FVC ratio (*p*=0.040), 1.8% higher percent predicted FEV_1 (p<0.001), and 1.4% higher percent predicted FVC (p=0.001), compared with those in the lowest quintile. The adjusted odds ratios of COPD for the highest versus lowest quintiles of intake were 0.85 (*p*=0.044) for total fiber, 0.83 (*p*=0.021) for cereal fiber, and 0.72 (*p*=0.005) for fruit fiber. This study provides the first evidence that dietary fiber is independently associated with better lung function and reduced prevalence of COPD.

Keywords

COPD; FEV_1; FVC; fiber; pulmonary function

Extensive research has focused on the protective effects of dietary fiber on cardiovascular diseases, including ischemic heart disease, stroke, peripheral arterial diseases, hypertension, and atherosclerosis (1). The antiinflammatory (2) and antioxidant (3,4) properties of fiber may contribute to cardiovascular protection.

Chronic obstructive pulmonary disease (COPD), characterized by airflow limitation that is not fully reversible, is an important cause of mortality and morbidity (5). The prevalence of and mortality from COPD is increasing, even in developed countries (5,6). Consistent with the potent inflammatory properties of tobacco smoke and the risk of COPD prominently associated with it (7), antiinflammatory nutrients may protect against the disease (8-12). A number of studies have found inverse associations between intake of antioxidant vitamins or fruits on

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respiratory symptoms or illness. In a large cohort of Chinese Singaporeans, higher consumption of fiber was protective against the development of symptoms of chronic bronchitis, independent of intake of antioxidant vitamins and fruit, and adjustment for fiber diminished or obliterated the beneficial associations with antioxidant vitamins or fruits (13). However, few studies have considered fiber in relation to lung function, respiratory symptoms or COPD.

The purpose of this study was to test the hypothesis that dietary intake of fiber is independently associated with better lung function and a lower prevalence of COPD. We examined this hypothesis in the middle-aged men and women sampled from four US communities by the Atherosclerosis Risk in Communities (ARIC) Study.

MATERIALS AND METHODS

Subjects

The design, objectives and quality control of the ARIC study have been reported in detail (14). Participants were sampled from four U.S. communities: Forsyth County, North Carolina; Jackson, Mississippi; northwest suburbs of Minneapolis, Minnesota; and Washington County, Maryland. The Jackson sample was 100 percent African-American and the other three were predominantly white. Eligible participants were interviewed at home, and then invited to a baseline clinical examination in 1987-1989, which was completed by 15,792 African American and white men and women aged 44 to 66 yrs. For this analysis, the lung function variables collected during visit 1 (the baseline examination, 1987-1989) were used in combination with the dietary data in a cross-sectional analysis. Institutional Review Boards at the participating centers approved the study.

Lung function testing and COPD

The main measures of lung function were the forced expiratory volume at 1 second (FEV_1), i.e., the volume of gas exhaled in the first second of expiration; the forced vital capacity (FVC), i.e., the total volume of gas exhaled; the ratio of FEV_1/FVC; and percent predicted FEV_1 and FVC. In accordance with American Thoracic Society criteria and a standardized protocol, trained clinic technicians used a Collins Survey II water-seal spirometer which was connected to an IBM PC/XT computer and controlled by the Pulmo-Screen II software system. Quality control was carefully conducted throughout the study, as described previously (15). Sex-specific predicted values for FEV_1 and FVC, adjusted for age and height, were computed from the equation of Crapo et al (16). For blacks, equation-derived predictions were multiplied by 0.88 (17).

We considered two COPD-related phenotypes. We defined chronic bronchitis using self-reported persistent cough and production of phlegm on most days for at least three consecutive months of the year for two or more years. We used Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria (FEV_1/FVC ratio <0.7 and $FEV_1 < 80\%$ predicted) to classify COPD based on spirometry, although postbronchodilator values were not available (18). We also created a composite COPD category of subjects who had either of the two phenotypes.

Dietary assessment

Participants' usual dietary intake over the preceding year was assessed using an interviewer-administered 66-item semi-quantitative food-frequency questionnaire (FFQ). The questionnaire was a modified version of the 61-item instrument designed and validated by Willett et al for self-administration (19). In the Nurses Health Study the correlation coefficient of energy-adjusted crude fiber between the questionnaire and four one-week dietary records was 0.58 (19). To improve completeness and accuracy, our questionnaire was administered by trained interviewers. Participants were asked to report the frequency of consumption of each food in 9 categories, ranging from never or < 1 time per month to ≥ 6 times per day. Interviewers also obtained additional information, including the brand name of the breakfast cereal usually consumed. Each participant's daily intake of various nutrients was computed by multiplying the daily servings of each food item by their nutrient content. The nutrient content of food items was taken primarily from US Department of Agriculture sources (20,21); dietary fiber content was from a publication by Paul and Southgate (22). All dietary factors in our analysis were adjusted for total energy using the residual method (23).

Other Covariates

Anthropometric measures were determined by trained, certified technicians following a standardized protocol. Body mass index (BMI) was calculated as weight (kg)/[height (m)]^2. Interviewers collected information on age, ethnicity, gender, smoking, environmental tobacco smoke (ETS), occupation, education, medical history, and other factors. For smoking history, participants were first classified as current smokers, former smokers and never smokers. Never and former smokers were classified as exposed to ETS if they reported being in close contact with smokers for more than 1 hour per week (24). Thus 5 strata for active and passive smoking were obtained: current smoker, former smoker with ETS, former smoker without ETS, never smoker with ETS, never smoker without ETS. Residence-based traffic density was calculated as measure of exposure to traffic-related air pollution (25).

Statistical analysis

We excluded persons who met the following criteria: ethnicity other than African American or white (n=48); African-Americans from Minnesota and Maryland field centers (n=55); missing data on spirometry (n=127) or dietary fiber (n=364); and missing or incomplete information for covariates, including active and passive smoking status (n=1,871), total energy intake (n=38), traffic exposure (n=1,724), and diabetes (n=148). The final study sample consisted of 11,897 adults.

The relation between fiber intake and lung function measurements was explored using linear regression. Our basic model included only age, sex, height and square of height. Based on previous literature we included the following additional factors in the adjusted models: study center, ethnicity, smoking status (current smoker, former smoker with ETS, former smoker without ETS, never smoker with ETS, never smoker without ETS), pack years, body mass index (BMI), occupation, education, diabetes status, traffic density, total energy intake, glycemic index, micronutrients (carotenoids, vitamins C, D, E, and omega-3 fatty acids) from both food and supplements, and cured meat (processed meat, bacon, and hot dog).

The association between fiber intake and binary outcomes (chronic bronchitis, emphysema, spirometry-defined COPD, and the composite COPD variable) was analyzed using multiple logistic regression. Similarly, we conducted analyses using both basic and adjusted models with the covariates listed above except height and square of height.

We analyzed energy-adjusted fiber intake according to quintiles. We estimated the adjusted values of lung function measurements at each quintile of intake, and odds ratios (ORs) of COPD comparing the highest to the lowest quintiles. Tests for linear trends across increasing quintiles of fiber intake used the median values in each quintile. Covariates that might modify the effects of fiber, such as gender, ethnicity, and smoking, were evaluated for possible inclusion as interaction terms with dietary fiber.

SAS (version 9.1.2, Cary, NC) software was used for all statistical analyses.

RESULTS

Table 1 shows the descriptive characteristics of the ARIC participants at visit 1, stratified by quintiles of energy-adjusted total dietary fiber. Participants with a higher fiber intake tended to have a higher intake of carotenoids, vitamins C, D, E, and omega-3 fatty acids, and a lower intake of cured meat. Subjects in the highest quintile of fiber intake were generally slightly older, more likely to be white, female, leaner, and were less likely to be current smokers.

Consistent with previous reports (26,27), the prevalence of spirometry-defined COPD (11.1%) (n=1,321) was much higher than that of symptom-based chronic bronchitis (5.6%) (n=669). The prevalence of COPD was 14.7% (n=1,753) when defined by either chronic bronchitis or spirometry. Among subjects with chronic bronchitis, 35.4% had spirometry-defined COPD, and 17.9% of those with spirometry-defined COPD had chronic bronchitis.

There was a statistically significant dose-response relationship between lung function (FEV_1, FVC, ratio of FEV_1/FVC, and percent predicted FEV_1 and FVC) and dietary fiber from all sources, in both basic (data not shown) and adjusted models (Table 2). Participants in the highest quintile of total fiber intake had 60.2 ml higher FEV_1 (p for trend across quintiles < 0.001), 55.2 ml higher FVC ($p = 0.001$), 0.4% higher FEV_1/FVC ratio ($p = 0.040$), 1.8% higher percent predicted FEV_1 ($p < 0.001$), and 1.4% higher percent predicted FVC ($p = 0.001$), compared with those in the lowest quintile. Similar patterns were seen for fiber intake from cereal and fruit sources (Table 2). Vegetable fiber was not significantly associated with any of the lung function measures (data not shown).

After multivariate adjustment, prevalences of chronic bronchitis and spirometry-defined COPD both declined across increasing quintiles of total fiber intake, but the associations were statistically significant only for spirometry-defined COPD (p for trend across quintiles = 0.035) (Table 3). For cereal fiber, we found statistically significant associations with both chronic bronchitis ($p = 0.028$) and spirometry-defined COPD ($p = 0.017$). For fruit fiber, ORs tended to decline with increasing quintiles of intake with trends statistically significant for chronic bronchitis ($p = 0.004$), but not for spirometry-defined COPD ($p = 0.083$). When COPD was defined by either chronic bronchitis or spirometry, the ORs for the highest quintile of intake compared with the lowest quintile were 0.85 ($p = 0.044$) for total fiber, 0.83 ($p = 0.021$) for cereal fiber, and 0.72 ($p = 0.005$) for fruit fiber. Similar to our findings for pulmonary function, vegetable fiber was not significantly associated with any COPD phenotypes (data not shown).

We examined whether sex, ethnicity, and smoking status modified the associations of fiber with FEV_1 and COPD (defined by either chronic bronchitis or spirometry). We observed statistically significant associations between total fiber and FEV_1 in all subgroups, with little evidence of interaction (Table 4). For COPD the tests for interaction were significant only for ethnicity (p for interaction = 0.003) (Table 5). We observed a significant association of total fiber with COPD in the whites (p for trend across quintiles = 0.016), but not in blacks (p = 0.300). Although subgroup analyses were significant only in males or current and past smokers, these differences were not statistically significant (p for interaction = 0.429 for gender and 0.275 for smoking).

We considered whether fiber intake attenuated associations of individual nutrients or foods previously associated with lung function or COPD. A statistically significant beneficial association of carotenoid intake with FEV_1 was eliminated after adjustment for fiber (Table S1 in the online supplement); likewise, a significant inverse association with preserved meats was attenuated by adjustment for fiber. None of the estimated vitamin intakes were associated with either of the COPD phenotypes examined.

DISCUSSION

In this cross-sectional analysis of middle-aged adults we found beneficial associations of dietary fiber from all sources and from cereal and fruit with lung function and COPD. Of note, these beneficial associations of higher fiber intake were not explained by greater intake of other dietary nutrients including carotenoids, vitamins C, D, E, omega-3 fatty acids, nor lower intake of cured meat, nor by a large array of risk factors for reduced pulmonary function and COPD.

Higher intake of dietary antioxidants (e.g. vitamins C and E, β-carotene) (28-31), foods rich in antioxidants (e.g. fruits and vegetables) (32-34), omega-3 fatty acids (35) and fish consumption (35-37) have been associated with better lung function and reduction of COPD symptoms and mortality; conversely, frequent cured meat consumption was associated with an obstructive pattern of lung function and increased odds of COPD (38). Some studies found stronger associations for fruit intake than for individual fruit-related nutrients such as vitamin C and carotenoids (9,11), suggesting other associated nutrients may be more relevant in protecting the lung from oxidative stressors. Dietary fiber is thought to contribute to the beneficial health effects on cardiovascular endpoints of intake of fruits, whole grain and vegetables (3,4,39), but has seldom been studied in relation to lung disease. In the Singapore Chinese Health Study, nonstarch polysaccharides, a major component of dietary fiber, reduced the incidence of chronic bronchitis symptoms (13). Relevant to interpretation of previous findings on diet and lung disease that did not consider the role of fiber, in the Singapore study, adjustment for fiber intake eliminated univariate associations with intake of antioxidant micronutrients or fruit (13).

The hypothesis that higher dietary intake of fiber might protect against reduced lung function and COPD is biologically plausible. Both airway inflammation and oxidative stress play roles in the pathogenesis of chronic bronchitis, emphysema (5) and deterioration of lung function (40). Our observed beneficial association of dietary fiber with lung function and COPD may be due to the antiinflammatory and/or antioxidant properties of fiber (2-4,41-46). Fiber intake has been associated with reduced level of C-reactive protein (43-46), a marker of systemic inflammation. Fiber may modulate inflammation by several mechanisms including slowing the absorption of glucose (47), decreasing lipid oxidation (2), or influencing the production of antiinflammatory cytokines by the gut flora (48). Another possibility is that some constituents of fiber, such as trace elements or associated nutrients (e.g. flavonoids), that we cannot assess from our questionnaire, may have beneficial effects on the lung (13,49). Another mechanism that theoretically could come into play is a substitution effect, replacing the intake of foods with detrimental effects. However, it is notable that in another study, fiber intake was protective for chronic bronchitis symptoms independently of a deleterious association with a dietary pattern characterized by high intake of preserved and fresh meat, sodium and refined carbohydrates (50). Further, the effect of fiber in our study persisted after adjustment for preserved meat which was related to increase risk of adverse respiratory events in two studies (38,50). Thus we believe that our study adds to growing evidence that fiber intake per se may have beneficial effects on the lung, independent of intake or other foods or nutrients or dietary patterns.

The concern might be raised that fiber intake simply reflects related behavior or clinical characteristics, such as smoking (Table 1), that influence respiratory risk. However, the association with dietary fiber remained significant after careful adjustment for smoking as well as a wide variety of demographic, lifestyle, and dietary characteristics. Moreover, the protective effect of dietary fiber on lung function was similar in both smokers and nonsmokers (Table 4) indicating that the protective effects of dietary fiber on lung function was independent of smoking behavior (51).

Neither sex, ethnicity, nor smoking status significantly modified the associations of total fiber intake with lung function measurements (Table 4). Finding a protective effect of fiber intake on lung function in both smokers and nonsmokers is not unexpected. In nonsmokers, fiber intake may protect against deleterious effects of indoor and ambient air pollutants (25). In stratified analyses for COPD, however, the effect of dietary fiber was limited to whites and a test for interaction by race was significant (Table 5). Similarly, Stevens et al reported a protective role of cereal fiber on the development of diabetes limited to white ARIC participants (52). The lack of association among African-Americans in ARIC may be due to the smaller sample size (2,798 African-Americans vs. 9,099 white participants), lower intake of dietary fiber (16.5% of African-Americans vs. 21.1% of white participants were in the highest quintile of total fiber intake), and lower prevalence of COPD (11.0% in African American vs. 15.9% in white participants). Although upon stratification by smoking the inverse association appeared to be limited to current and past smokers, the test for interaction by smoking was not statistically significant and as expected, there were far fewer cases of COPD among never smokers, limiting power.

The association between carotenoids intake and lung function was attenuated after adjustment for fiber (Table S1). This is consistent with a previous report that the inverse association between antioxidant vitamins and chronic bronchitis symptoms diminished after adjustment for fiber (13). The earlier studies on anti-oxidant vitamins and lung function did not consider the role of fiber (28-30), and therefore it is unclear whether the previously reported associations with those vitamins were independent of fiber intake.

We found significant associations of lung function and COPD with cereal and fruit fiber, but not with vegetable fiber. These findings are consistent with a pooled analysis of studies of diet and coronary heart disease in which fiber from cereal and fruit, but not from vegetables, was inversely associated with disease risk (53). The lack of association with vegetable fiber also mirrors results from the Singapore Chinese Health Study, a population with low intake of whole grain cereals, in which fiber from fruit and soy, but not from vegetables, was associated with reduced risk of chronic bronchitis symptoms (13). It is possible that fiber from cereal or fruit may have physiologic effects that are more beneficial to respiratory system than fiber from vegetables.

Limitations of our analysis should be noted. The GOLD criteria for COPD are based on post-bronchodilator FEV_1 (54); however, as in other large epidemiologic studies (55-58), we did not administer a bronchodilator. Thus, we cannot distinguish reversible from nonreversible airway obstruction and as a result, our spirometry-defined COPD group may contain asthmatics. Further, a temporal relationship between fiber intake and lung function and COPD can not be established in this cross-sectional analysis. It is possible that participants with symptoms or a diagnosis of COPD could have responded by changing to a healthier diet with increased intake of fruits and whole grains. However, few studies linked diet with COPD during the study period (1987-1989), making it quite unlikely that participants with COPD would have been advised to make these dietary changes. Although we had two measures of pulmonary function at both visits 1 and 2, they were only three years apart which is probably insufficient to detect longitudinal effects of fiber intake (59). Nevertheless, we performed supplementary longitudinal analyses (Table S2); we found significant inverse associations of declines in FEV_1, FVC and percent predicted FEV_1 with cereal fiber, but not with total or fruit fiber.

We conclude that higher dietary intake of fiber was related to better lung function and reduced prevalence of COPD. These beneficial associations with fiber intake were independent of other nutrients or dietary patterns that have been suggested to have either beneficial or deleterious effects on respiratory health. To our knowledge, this is the first study to examine fiber intake in relation to pulmonary function and COPD. Our findings suggest that greater intake of dietary fiber may protect against deterioration of lung function, and possibly against COPD.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1

Baseline characteristics of the ARIC study population (1987-1989) stratified by energy-adjusted total dietary fiber intake (n=11,897) [*]

	Quintiles of energy-adjusted intake of total fiber				
	1 (lowest)	**2**	**3**	**4**	**5**
Dietary intake[†]					
Total fiber (g/d)	9.5	13.7	16.4	19.5	26.7
Cereal fiber (g/d)	2.5	3.2	3.5	3.9	4.5
Fruit fiber (g/d)	1.5	2.8	3.9	5.0	7.6
Vegetable fiber (g/d)	2.2	3.4	4.1	5.1	7.5
Carotenoids (IU)	3,307	5,219	6,330	8,041	11,584
Vitamin C (mg)	95.2	106.0	116.6	131.0	158.0
Vitamin D (IU)	205.7	215.4	218.8	227.1	233.7
Vitamin E (mg)	3.5	4.4	4.7	5.2	6.2
Omega-3 fatty acids (g)	0.18	0.22	0.24	0.27	0.33
Cured meat (servings/week)	3.9	3.7	3.3	2.8	2.2
Participant characteristics					
Age (yr)	53.2	53.8	54.1	54.5	55.1
Sex (female %)	41.2	56.4	61.4	63.2	63.5
BMI (kg/m^2)	27.7	27.5	27.6	27.5	27.3
Race (Black %)	28.5	26.8	22.7	20.2	19.4
Smoking					
Current smoker (%)	42.2	32.9	25.2	21.8	20.5
Former smoker (%)	25.3	26.9	28.1	29.1	30.6
Never regular (%)	32.5	40.2	46.7	49.1	48.9

[*] Data are presented as mean intake or percentage unless otherwise noted.

[†] Except total energy intake, all dietary factors were energy-adjusted.

TABLE 2

Mean values of adjusted lung function measurements across quintiles of energy adjusted fiber intake among ARIC participants (1987-1989), n=11,897 *

	Quintiles of energy-adjusted fiber intake					Difference between quintiles 5 and 1 (95% CI)	p value for trend †
	1(lowest)	2	3	4	5		
Total fiber							
Median intake (g/d)	10.2	13.7	16.4	19.4	25.0		
FEV_1 (ml)	2,726	2,744	2,755	2,786	2,786	60.2 (27.7, 92.7)	<0.001
FVC (ml)	3,663	3,687	3,692	3,728	3,718	55.2 (18.2, 92.3)	0.001
FEV_1/FVC (%)	74.7	74.6	74.9	74.9	75.1	0.4 (-0.1, 0.9)	0.040
Predicted FEV_1(%)	91.2	91.6	92.0	93.1	93.0	1.8 (0.8, 2.9)	<0.001
Predicted FVC (%)	98.0	98.6	98.8	99.8	99.4	1.4 (0.4, 2.4)	0.001
Fiber from cereal							
Median intake (g/d)	1.6	2.5	3.2	4.0	5.8		
FEV_1 (ml)	2,739	2,756	2,748	2,771	2,787	48.6 (19.5, 77.7)	<0.001
FVC (ml)	3,679	3,695	3,693	3,705	3,719	40.3 (7.1, 73.4)	0.016
FEV_1/FVC (%)	74.6	74.8	74.6	74.9	75.2	0.5 (0.1, 1.0)	0.015
Predicted FEV_1(%)	91.6	92.2	91.9	92.5	93.0	1.4 (0.4, 2.4)	0.004
Predicted FVC (%)	98.5	98.9	98.9	99.1	99.4	0.9 (0.1, 1.8)	0.041
Fiber from fruit							
Median intake (g/d)	0.8	2.1	3.5	5.1	8.1		
FEV_1 (ml)	2,731	2,753	2,765	2,755	2,797	65.4 (34.4, 96.4)	<0.001
FVC (ml)	3,671	3,694	3,704	3,691	3,733	62.1 (26.8, 97.4)	0.002
FEV_1/FVC (%)	74.6	74.7	74.8	74.9	75.1	0.5 (0.0, 0.9)	0.022
Predicted FEV_1(%)	91.4	91.7	92.3	92.1	93.5	2.1 (1.1, 3.1)	<0.001
Predicted FVC (%)	98.3	98.6	99.1	98.8	99.9	1.7 (0.7, 2.6)	<0.001

[*] Covariates included age, sex, height, square of height, study center, ethnicity, smoking status (current smoker, former smoker with ETS, former smoker without ETS, never smoker with ETS, never smoker without ETS), pack years, BMI, occupation, education, diabetes status, traffic density, total energy intake, glycemic index, micronutrients (carotenoids, vitamins C, D, E, and omega-3 fatty acids) from both food and supplements, cured meat, and other sources of fiber (total fiber intake not adjusted for the specific fiber types).

[†] Tests for linear trends across increasing quintiles of fiber intake used the median values in each quintile.

TABLE 3

Adjusted odds ratios for COPD-related phenotypes in relation to energy adjusted fiber intake among ARIC participants (1987-1989), n=11,897*

	Quintiles of energy-adjusted fiber intake					***p* value for trend†**
	1(lowest)	**2**	**3**	**4**	**5**	
Total fiber						
Chronic bronchitis	1	1.10 (0.86, 1.41)	0.87 (0.67, 1.14)	0.87 (0.66, 1.15)	0.87 (0.64, 1.19)	0.185
Spirometry-defined COPD	1	0.95 (0.78, 1.15)	0.85 (0.70, 1.05)	0.80 (0.65, 1.00)	0.80 (0.63, 1.02)	0.035
COPD by any definition above	1	1.01 (0.85, 1.20)	0.91 (0.76, 1.09)	0.83 (0.68, 1.01)	0.85 (0.68, 1.05)	0.044
Fiber from cereal						
Chronic bronchitis	1	1.02 (0.80, 1.31)	0.81 (0.62, 1.05)	0.83 (0.64, 1.08)	0.77 (0.58, 1.01)	0.028
Spirometry-defined COPD	1	0.89 (0.73, 1.09)	0.99 (0.81, 1.20)	0.78 (0.63, 0.96)	0.79 (0.64, 0.98)	0.017
COPD by any definition above	1	0.93 (0.78, 1.11)	0.95 (0.80, 1.13)	0.77 (0.64, 0.93)	0.83 (0.69, 1.01)	0.021
Fiber from fruit						
Chronic bronchitis	1	0.73 (0.57, 0.94)	0.77 (0.60, 0.99)	0.67 (0.51, 0.88)	0.63 (0.47, 0.84)	0.004
Spirometry-defined COPD	1	0.94 (0.78, 1.14)	0.89 (0.73, 1.08)	0.90 (0.72, 1.11)	0.81 (0.64, 1.03)	0.083
COPD by any definition above	1	0.82 (0.69, 0.98)	0.86 (0.72, 1.03)	0.82 (0.68, 0.99)	0.72 (0.59, 0.89)	0.005

[*] Covariates included age, sex, study center, ethnicity, smoking status (current smoker, former smoker with ETS, former smoker without ETS, never smoker with ETS, never smoker without ETS), pack years, BMI, occupation, education, diabetes status, traffic density, total energy intake, glycemic index, micronutrients (carotenoids, vitamins C, D, E, and omega-3 fatty acids) from both food and supplements, cured meat, and other sources of fiber (total fiber intake not adjusted for the specific fiber types). N=669 for chronic bronchitis, 1,321 for spirometry-defined COPD, and 1,753 for COPD by either definition.

[†] Tests for linear trends across increasing quintiles of fiber intake used the median values in each quintile.

TABLE 4

Mean FEV_1 (ml) across quintiles of energy adjusted intake of total fiber, stratified by sex, ethnicity, and smoking status (1987-1989) [*]

	No. of subjects	**Quintiles of energy-adjusted intake of total fiber**					**Difference in FEV_1 (ml) between quintiles 5 and 1 (95% CI)**	***p* value for trend**[†]	***p* value for interaction**[‡]
		1 (lowest)	**2**	**3**	**4**	**5**			
Sex									
Female	6,799	2,325	2,337	2,354	2,376	2,369	44.0 (7.2,80.9)	0.006	0.394
Male	5,098	3,208	3,234	3,238	3,279	3,287	79.8 (22.5,137.0)	0.003	
Ethnicity									
Black	2,798	2,506	2,524	2,550	2,557	2,575	68.4 (5.3,131.5)	0.021	0.612
White	9,099	2,860	2,877	2,880	2,921	2,921	60.7 (22.7,98.7)	<0.001	
Smoking status									
Never	5,174	2,771	2,779	2,785	2,821	2,822	50.7 (6.8,94.5)	0.005	0.903
Current/past	6,723	2,695	2,719	2,734	2,759	2,759	64.2 (17.2,111.1)	0.003	

[*] Covariates included age, sex, height, square of height, study center, ethnicity, smoking status (current smoker, former smoker with ETS, former smoker without ETS, never smoker with ETS, never smoker without ETS), pack years, BMI, occupation, education, diabetes status, traffic density, total energy intake, glycemic index, micronutrients (carotenoids, vitamins C, D, E, and omega-3 fatty acids) from both food and supplements, and cured meat.

[†] Tests for linear trends across increasing quintiles of fiber intake used the median values in each quintile.

[‡] Likelihood ratio test for interaction (effect modification) by sex, ethnicity, and smoking status.

Table 5

Adjusted ORs for COPD across quintiles of energy adjusted intake of total fiber, stratified by sex, ethnicity, and smoking status [*]

	No. of subjects/cases	**Quintiles of energy-adjusted intake of total fiber**					***p* value for trend**[†]	***p* value for interaction**[‡]
		1(lowest)	**2**	**3**	**4**	**5**		
Sex								
Female	6,799/756	1	1.01 (0.77, 1.33)	0.90 (0.68,1.19)	0.84 (0.62,1.13)	0.92 (0.67,1.28)	0.455	0.429
Male	5,098/997	1	1.01 (0.80,1.26)	0.90 (0.71,1.15)	0.83 (0.63,1.07)	0.77 (0.57,1.03)	0.041	
Ethnicity								
Black	2,798/307	1	1.00 (0.68,1.47)	1.18 (0.79,1.75)	1.00 (0.63,1.58)	1.32 (0.81,2.15)	0.300	0.003
White	9,099/1,446	1	1.01 (0.84,1.23)	0.85 (0.70,1.05)	0.81 (0.65,1.00)	0.79 (0.62,1.00)	0.016	
Smoking status								
Never	5,174/291	1	1.17 (0.76,1.80)	0.97 (0.62,1.50)	1.02 (0.65,1.59)	1.13 (0.70,1.84)	0.772	0.275
Current/past	6,723/1,462	1	0.99 (0.82,1.19)	0.90 (0.73,1.10)	0.79 (0.63,0.98)	0.78 (0.61,0.99)	0.013	

[*] COPD defined by either chronic bronchitis (n=669) or spirometry-defined COPD (n=1,321) or both (n=1,753). Covariates included age, sex, study center, ethnicity, smoking status (current smoker, former smoker with ETS, former smoker without ETS, never smoker with ETS, never smoker without ETS), pack years, BMI, occupation, education, diabetes status, traffic density, total energy intake, glycemic index, micronutrients (carotenoids, vitamins C, D, E, and omega-3 polyunsaturated fatty acids) from both food and supplements, and cured meat.

[†] Tests for linear trends across increasing quintiles of fiber intake used the median values in each quintile.

[‡] Likelihood ratio test for interaction (effect modification) by sex, ethnicity, and smoking status.