Title: **The Relationship between Dietary Fiber Intake and Lung Function in NHANES**

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Abstract

Purpose: Extensive research supports a protective effects of a high fiber diet in certain disease states; however, little is known about its relationship to lung health. The National Health and Nutrition Examination Surveys (NHANES) contain spirometry measures and dietary intake information, allowing us to assess this relationship.

Methods: Participants included 1,921 adults who had spirometry measurements and fiber intake available. The primary outcomes were lung function measurements, including FEV_1, FVC, and percent predicted FEV_1 and FVC. We also conducted acategorical analysis of fiber intake and airflow restriction and obstruction based on GOLD and Spirometry Grade (SG) classifications. Multivariable regression models were used to look at the association of lung function measurements with dietary fiber intake after adjustment for relevant confounders. All analyses accounted for the weighted data and complex design of the NHANES sample.

Results: Subjects in the highest quartile intake of fiber had mean FEV_1 and FVC measurements that were 82 mL and 129 mL higher that the lowest quartile of intake (p=0.05 and 0.01, respectively), and mean percent predicted FEV_1 and FVC values that were 2.4 and 2.8 percentage points higher (p=0.07 and 0.02, respectively). In the categorical analysis, higher fiber intake was associated with a higher percentage of of those with normal lung function (p=0.001) and a significant decline in the proportion of participants with airflow restriction (p=0.001).

Conclusion: Low fiber intake was associated with reduced measures of lung function. A diet rich in fiber-containing foods may play a role in improving lung health.

Keywords: Diet, fiber, lung function, restrictive lung disease, obstructive lung disease

Introduction Lung diseases are a major public health problem, with chronic obstructive pulmonary disease (COPD) now the third leading cause of death in the world [1]. Lung function is a predictor of mortality in the general population as well as in patients with lung disease [2], making maintaining lung function an important goal in the prevention of COPD and a major public health objective [3]. Despite this, few preventative interventions other than smoking cessation have been identified. While smoking remains an important risk factor, it has become clear that other factors contribute to the risk of lung disease, and evidence has revealed that diet may be an important consideration in lung health [4-17].

There is extensive research supporting the protective effects of a high fiber diet in certain disease states, including heart disease and cancer [18-20]. However, little is known about fiber and its relationship to lung health. Dietary fiber has been shown to exhibit both anti-inflammatory and anti-oxidant properties [18,21-26] which have been implicated in both the development and progression of lung disease [27-29].

The National Health and Nutrition Examination Surveys (NHANES) include spirometry measures and dietary intake information, allowing us to test the hypothesis that lower fiber intake will be associated with reduced lung function in a sample of United States adults. Therefore, the purpose of this study was to examine if intake of dietary fiber is associated with measures of lung function and presence of airflow restriction or obstruction in a United States adult population, and possible mediators of this relationship, including systemic inflammation reflected in differences in C-reactive protein (CRP) measurements. Some of the results of this study have been previously reported in the form of an abstract [30].

Methods

<u>Subjects</u> This analysis includes adults 40 to 79 years of age in the NHANES cycle 2009-2010 who had pre-bronchodilator spirometry measurements available. Subjects with self-reported

energy intake outside a plausible range (women: <600 or >6,000 kcal/day; men: <800 or >8,000 kcal/day) were excluded. Detailed methods and protocols for the NHANES study have been previously reported, including informed consent procedures for all participants [31]. As the data used in our study is freely available in the public domain, the study was exempt from human subjects review.

Lung Function Outcomes Pre-bronchodilator spirometry was offered to participants aged 6-79 years in NHANES 2007-2010. Protocols for these measurements have been summarized elsewhere [32-25]. Only spirometry measurements conforming to the American Thoracic Society standards were used in this analysis. Lung function was also expressed as a percent of predicted using the spirometric reference values from the third NHANES [35].

Respiratory Phenotype Determination: The Global Initiative for Chronic Obstructive Lung Disease (GOLD) classification of COPD was used to establish the presence and severity of airflow obstruction according to GOLD groups [36]. Alternate classification methods for COPD have also been proposed, including the COPD Foundation Spirometry Grade (SG) classification where those with no airflow obstruction are sub-classified according to normal lung function and those with submaximal spirometry ($FEV_1/FVC \geq 0.70$, $FEV_1 < 80\%$ predicted) [37]. Our analysis therefore included three comparator groups: 1). a group with normal spirometry ($FEV_1/FVC \geq 0.70$, $FEV_1 \geq 80\%$predicted); 2). a group who met the criteria for classification for a "restrictive" spirometric pattern; ($FEV_1/FVC \geq 0.70$, $FEV_1 < 80\%$ predicted); and 3). those with airflow obstruction ($FEV_1/FVC < 0.70$) where severity was defined according to $FEV_1\%$ predicted into SG 1-3 or GOLD 1-4. The definitions and distributions of these classifications are presented in Table 1.

Dietary Assessment Dietary intake in the NHANES survey was determined from 2 interviewer administered 24 hour recalls, developed and validated by the U.S. Department of Agriculture.

Participants' dietary intake of total fiber in grams per day was calculated [16,38]. The use of fiber supplements was not included because of limited information.

Other Covariates To assess smoking status, survey participants were asked about current and past tobacco use. Smoking status was defined as: never, former (smoked >100 cigarettes in lifetime but does not currently smoke), and current (smoked >100 cigarettes in lifetime and smokes currently). Subject height and weight were measured during the clinical examination and were used to calculate body mass index (BMI). BMI categories were created based on the World Health Organization BMI classifications [39] and participants were categorized as follows: underweight: <18.5, normal range: 18.5-24.9, overweight: 25-30, and obese: >30. The ratio of family income to poverty levels variable was used to adjust for socioeconomic status. C-reactive protein (CRP) concentrations were included in the analysis as a biomarker of inflammation.

Statistical Analysis Mean and standard errors were used for descriptive statistics. To incorporate the complex, multistage sampling design of the NHANES in the statistical analysis, the SAS procedures SURVEYFREQ, SURVEYMEANS, SURVEYREG, and SURVEYLOGISTIC were used. Univariate and multivariable regression models were used to look at the association of lung function measurements and respiratory phenotypes with quartiles of dietary fiber intake. The multivariable regression models were adjusted for the possible confounders of height, age, gender, BMI, smoking, socioeconomic status, CRP, and energy intake. On the basis of other literature, we also adjusted for the following factors: intakes of vitamin E, alpha-carotene, beta-carotene, beta-cryptoxanthin, lycopene, lutein + zeaxanthin, vitamin C, and cured meat [28,29,40]. Odds ratios and 95% confidence intervals were determined using PROC SURVEYFREQ.

As smoking remains the most important cause of respiratory disease, we analyzed the interaction between fiber intake and smoking status. A similar analysis was performed for BMI based on the BMI categories described above. In addition, recent literature has indicated that diet may affect lung function differently based on gender [16], therefore a test for interaction between fiber intake and gender was conducted and analysis was stratified based on gender for variables with a positive interaction signal. All analyses accounted for the weighted data and complex design of the NHANES sample. A p-value< 0.05 was considered statistically significant.

Results The final number of eligible participants was 1,921. Overall, the cohort was 50.2% male and 49.8% female. The mean age of the participants was 52.8 years with a mean BMI of 29.2. Participants with a higher fiber intake tended to have a lower BMI, a higher intake of fruits, vegetables, and whole grains, lower CRP, and higher energy intake than those with lower fiber intakes. Lower intake of fiber was also associate with smoking. The demographic characteristics of the sample by quartile of fiber intake are given in Table 2.

There was a statistically significant relationship between lung function measurements and dietary fiber intake in both univariate models (data not shown) and multivariable models (Table 3). After adjusting for confounders (age, height, BMI, gender, energy intake, smoking status, socioeconomic status, CRP, height and intake of other vitamins), participants in the highest quartile intake of fiber intake (>17. 5 gms/day) had mean FEV_1 and FVC measurements that were 82 mL and 129 mL higher than the lowest quartile of intake (<10.5 gms/day) (p=0.05 and 0.01, respectively). Mean percent predicted FEV_1 and FVC values were 2.4 and 2.8 percentage points higher (respectively) in participants with the highest quartile intake when compared to participants in the lowest fiber intake quartile (p=0.07 and 0.01, respectively). In contrast to the other lung function parameters, where we found no gender effect with daily fiber intake, for FVC an effect was found (p=0.003 for males but not females (p=0.84). There was no association between fiber intake and FEV_1/FVC ratio.

To determine if associations differed by source of fiber, additional analysis was conducted for servings/day of fruits/vegetables/legumes (cups/day) and daily whole grain intake (ounce equivalents/day). Significant associations were present for intake of fruit/vegetables/legume (Table 3), with participants who were in the highest quartile for daily fruit/vegetable/legume intake having mean FEV_1 and FVC 107 mL and 127 mL higher, respectively, than those in the lowest quartile (p=0.001, p=0.006), and mean percent predicted FEV_1 and FVC values that were 3.3% and 2.8% higher than participants in the lowest quartile intake (p=0.0009 and 0.007, respectively). There was no association between lung function measurements and daily whole grain intake (data not shown).

To investigate whether smoking status modified the associations of fiber with lung function, each of the lung function outcomes were evaluated with fiber intake, smoking classification, and the interaction between smoking and fiber intake. There was no significant interaction between smoking and fiber for any of the outcomes (interaction terms p>0.10). Similar results were found for BMI, with no statistically significant interactions found between BMI and fiber intake related to any of the lung function outcomes.

There was evidence of relationship between fiber intake, normal lung function and airflow restriction. With increasing daily fiber intake, the percentage of those with normal lung function increased (50.1% vs. 68.3% for Q1 vs. Q4, p=0.001) although the effect was attenuated at quartiles 3 and 4 (Figure 1). For increasing daily fiber intake, there was a significant decline in the proportion of participants with airflow restriction (29.8% vs. 14.8% for Q1 vs. Q4, p=0.001) which again was attenuated at the higher quartiles (Figure 2). There was no relationship between daily fiber intake and severity of airflow obstruction (data not shown).

Discussion

In this analysis of the population-based NHANES study, we found that low fiber intake was associated with lower lung function. These associations were consistent across sub-categories of smoking and BMI. Of note, the beneficial association of high dietary fiber intake was independent of antioxidant intake, intake of cured meat, and other possible dietary risks associated with lung function decline. While we found no effect of dietary fiber on the prevalence of airflow obstruction (SG-1-3 or GOLD 1-4) we did find a greater prevalence of airflow restriction group in those with lowest dietary fiber intake (p=0.0001). We believe the failure to identify an association with spirometric-defined airflow obstruction may be the consequence of the low smoking exposure in this group and the overall low prevelance of COPD. Our results are consistent with other cross-sectional studies showing there is a strong fiber-smoking interaction on FEV_1 that is considerably weaker when never smokers are analyzed [9]. Our results build upon similar associations in earlier studies, including an analysis of the Atherosclerosis Risk in Communities (ARIC) study that found participants in the highest quintile of fiber intake had higher lung function measurements than those in the lowest quintile [28]. Varraso and Hirayama have both reported significant, independent associations between total fiber intake and risk of COPD [29,41]. Other studies have demonstrated that higher fiber intakes are associated with 40-50% reduction in respiratory related deaths, compared to 25-30% reductions for cardiovascular disease [42,43]. Taken together, these findings suggest dietary fiber has considerable relevance to lung health, notably impaired lung function and reduced respiratory mortality.

Intake of fruits, vegetables and legumes were associated with lung function in our study independent of intake of antioxidants previously associated with lung function [44]. Several studies have found stronger associations with intakes of whole fruit when compared to individual fruit-related nutrients [6,11,45,46] such as vitamin C, suggesting that other compounds, or the interaction of these compounds, may be more relevant. Dietary fiber has been one of the compounds speculated to contribute to the positive effect of fruits and vegetables on preserving lung function [9]. Indeed adjustment for fiber has eliminated univariate associations between fruit intake and FEV_1 [47]. Interestingly, our results did not show an association between intakes of whole grain foods and lung function, however whole grain intake may be poorly estimated in only 2 days of diet recalls. The lack of this relationship in our study conflicts with previous studies of fiber intake and COPD which stratified by fiber source and found the effects were due mainly to cereal fibers [29]. The relationship between healthy diet and better lung health in relastion to COPD was reported by Varraso and colleagues using a “Healthy Eating Index” [16]. Current evidence is not conclusive about which fiber containing foods are most beneficial for COPD. Fiber occurs in both soluble and insoluble forms, and studies attempting to stratify by fiber type have faced the challenge that foods usually contain a mix of both soluble and insoluble fibers, making it difficult to determine if one type is more accountable.

There are several plausible mechanisms through which intake of fiber may impact lung function and predispose to airflow restriction, and risk of COPD. Systemic inflammation is considered an important sub-phenotype of COPD [48,49], and there are a growing number of studies that show CRP is a marker of systemic inflammation, activation of the innate immune system and a possible effector molecule in vascular disease [50-52]. Higher intakes of dietary fiber have been associated with reduced systemic inflammation and CRP levels [53], and CRP levels have been shown to have an inverse relationship with lung function and respiratory morbidity [50,54-60]. Consistent with other studies we did find that a higher fiber intake was associated with lower CRP (Table 2) [61].

Attenuation of systemic inflammation may be only one of the mechanisms through which fiber impacts lung function. Dietary fiber has been shown to change the composition of the gut microbiome, in particular altering the ratio of Firmicutes to Bacteroidetes [61], consequently increasing the concentrations of short-chain fatty acids (SCFA). These by-products of fiber fermentation in the gastrointestinal tract are found in the systemic circulation and have several relevant protective functions with regard to lung function and COPD, including regulation of neutrophils [62], and attenuating pulmonary inflammation and epithelial-based protection against bacterial infection [63].

Our finding showing a trend toward a greater prevalence of those classified as airflow restriction with low dietary fiber intake is novel. This airflow restrictive subgroup, which constituted 22.6% of our older NHANES sample, includes those with a normal FEV_1/FVC ratio but proportionately reduced FVC and FEV_1. This group has also been called PRISm, for Preserved Ratio Impaired Spirometry, and has a reported prevalence of 5-18% in other studies (12% in COPDGene) [64,65]. This group is highly heterogeneous as much as three sub-phenotypes defined in COPDGene as “restrictive”, “early COPD” and “metabolic” [66]. Recent evidence shows that many of the people in this subgroup have systemic inflammation, poor exercise capacity and emphysema on computed tomography scanning, with or without airway inflammation [64]. This group remains poorly characterized and invariably excluded from studies of COPD. It is possible this group represents a separate and unique pulmonary phenotype which is, according to this study, significantly over-represented in those with low dietary fiber intake. To our knowledge, this is the first study to examine the association between dietary fiber intake and lung function with regards to this otherwise poorly understood subgroup. As this subgroup has a high prevalence of co-morbid conditions, and is highly symptomatic despite not meeting traditional COPD criteria, they may represent a group that might benefit from targeted dietary interventions to improve overall outcomes. However, it is also possible that evidence of this relationship given was driven by residual confounding from obesity that was not well captured by BMI. BMI is an imprecise measure of obesity and may not fully account for factors such as distribution of fat mass. As truncal adipostity has been associated with lung function, it is possible this may explain some of the the association between diet and a restrictive airflow pattern [66-68].

Our study has several limitations. First, the NHANES data we analyzed is cross-sectional so we cannot evaluate any temporal relationships, such as dietary fiber effects on lung function decline, nor can we establish causality. It could be proposed that fiber is a surrogate measure for an overall healthy lifestyle. Indeed, the recent study by Varraso and colleagues serves to stress the importance of the overall diet quality in pulmonary health [16]. Studies have also shown that increased intake of catechins and flavonoids are positively associated with FEV1[69]. Improving the overall quality of the diet may drive an individual's intake towards a more plant-based diet, which would also be a diet rich in other beneficial nutrients such as phytochemicals, antioxidants, flavonoids, or ligands. These nutrients may work in a synergistic fashion and are much less likely to be accurately captured in current dietary studies where recall over relatively short time periods are traditionally used to assess long-term intake. As lung function reflects both maximal lung function attained in early adulthood and lung function lost with aging [70], it is surprising we find an association at all between dietary fiber intake and contemporaneous lung function measurements. Second, serum levels of nutritional antioxidatns have been associated with lung function [71,72], and other studies of dietary fiber intake and lung function have adjusted for this [73]. Serum levels of anti-oxidant nutrients were not available for this NHANES cycle;however, we did include adjustment for intakes of these nutrients in our models. Adjustment for physical activity, which is relevant to dietary choices, was not adjusted for in this analysis and remains a potential sources of confounding. Third, this study used pre-bronchodilator measurements for lung function rather than post-bronchodilator values so it is harder to extrapolate our findings on dietary fiber intake and lung function in this study to COPD. In this study we have used the fixed ratio (FEV_1/FVC) to define the presence of airflow limitation, consistent with other dietary studies, and found comparable results using the lower limit of normal. Our study does have a major strength in our ability to use spirometry measurements for identifying the presence of airflow limitation and accurately distinguish those with sub-normal lung function, as opposed to the self-reported diagnosis of COPD used in many epidemiological studies.

Conclusions Low dietary fiber intake was associated with reduced measures of lung function, an increased prevalence of participants with airway restriction. A diet rich in fiber-containing foods may play a role in improving lung health.

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Table 1: Comparison of population distributions according to definitions of SG grade and GOLD classification based on pre-bronchodilator spirometry.

	Spirometry Grade (SG) classification				GOLD classification			
Category	**SG classification**	**Spirometry definition**	**N (%)**	**Subtotals**	**GOLD classification**	**Spirometry definition**	**N (%)**	**Subtotals**
Normal	**SG-0**	$FEV_1/FVC \geq 0.7$ and $FEV_1 \geq 80\%$ predicted	**1196 (62.3%)**	**1196 (62.3%)**	**Normal**	$FEV_1/FVC \geq 0.7$	**1628 (84.7%)**	**1628 (84.7%)**
Airflow Retriction	**SG-U***	FEV1/FVC ≥0.7 and $FEV_1<80\%$ of predicted FEV_1	**432 (22.5%)**	**432 (22.5%)**				
Airflow obstruction	**SG-1**	$FEV_1/FVC<0.7$ and $FEV_1 \geq 60\%$ predicted	**238 (12.4%)**		**GOLD 1**	$FEV_1/FVC <0.7$ and $FEV_1 \geq 80\%$ predicted	**128 (6.7%)**	
					GOLD 2	$FEV_1/FVC<0.7$ and $50\% \leq FEV_1 < 80\%$ predicted	**136 (7.0%)**	
	SG-2	$FEV_1/FVC <0.7$, $30\% \leq FEV_1 <60\%$ predicted	**53 (2.8%)**	**293 (15.3%)**	**GOLD 3**	$FEV_1/FVC<0.7$ and $30\% \leq FEV_1 <50\%$ predicted	**27 (1.4%)**	**293 (15.3%)**
	SG-3	$FEV_1/FVC <0.7$, $FEV_1 <30\%$ predicted	**2 (0.1%)**		**GOLD 4**	$FEV_1/FVC<0.7$ and $FEV_1 <30\%$ of predicted	**2 (0.1%)**	
	Totals		**1921**	**1921**			**1921**	**1921**

* Also called “unclassified”

Table 2: Participant characteristics stratified by energy-adjusted fiber intake quartile

	Fiber Intake Quartile Mean (SE)				
Characteristic:	**<10.75 grams/day (n=360)**	**10.75-<13.46 grams/day (n=461)**	**13.46-17.5 grams/day (n=529)**	**>17.5 grams/day (n=571)**	**P-value**
Continuous variables Mean (SD)					
Age, yr	52.9 (0.5)	53.1 (0.5)	52.8 (0.5)	52.5 (0.3)	0.76
FEV_1 (L)	2.6 (0.04)	3.0 (0.04)	3.1 (0.05)	3.2 (0.05)	<0.0001
FEV_1, %pred	80.9 (0.8)	86.6 (0.8)	89.0 (1.0)	90.6 (0.5)	<0.0001
FVC (L)	3.3 (0.04)	3.9 (0.05)	4.1 (0.06)	4.3 (0.06)	<0.0001
FVC, %pred	82.3 (0.7)	87.2 (0.8)	90.0 (0.9)	92.7 (0.6)	<0.0001
FEV_1/FVC ratio	0.76 (0.005)	0.77 (0.005)	0.76 (0.003)	0.76 (0.003)	0.079
Socioeconomic Status (income:poverty status ratio)	2.96	3.55	3.56	3.68	0.007
Fruit/vegetable/legume intake (cups/day)	1.5 (0.04)	2.1 (0.03)	2.8 (0.04)	3.6 (0.04)	<0.0001
Whole grain intake (ounces/day)	0.22 (0.02)	0.47 (0.03)	0.89 (0.04)	2.4 (0.04)	<0.0001
C-Reactive protein (mg/dL)	0.47 (0.5)	0.41 (0.06)	0.31 (0.04)	0.31 (0.05)	0.01
Energy intake (kcals/day)	1868.4 (48.8)	2076.7 (46.6)	2224.9 (48.5)	2368.9 (42.3)	<0.0001
Cured meat intake (times per day)	0.22 (0.3)	0.25 (0.01)	0.27 (0.01)	0.26 (0.01)	0.37
Vitamin E intake (as α-tocopherol, mg)	6.7 (0.38)	7.9 (0.3)	9.2 (0.3)	9.3 (0.3)	<0.0001
Alpha-carotene intake (mcg)	325.9 (45.5)	323.3 (27.2)	505.6 (114.2)	533.8 (27.7)	0.0005
Beta-carotene intake (mcg)	1982.1 (284.5)	2053.9 (161.6)	2742.3 (312.6)	2863.5 (27.7)	0.019
Beta-cryptoxanthin intake (mcg)	55.5 (10.4)	73.4 (7.8)	77.4 (5.5)	126.9 (20.0)	0.026
Lycopene intake (mcg)	3565.7 (468.3)	5105.0 (634.2)	6331.4 (591.9)	6156.9 (653.0)	0.001
Lutein + zeaxanthin intake (mcg)	1402.5 (277.9)	1692.4 (192.5)	1972.8 (191.5)	1965.5 (241.5)	0.32
Vitamin C intake (mg)	59.0 (6.8)	87.3 (7.9)	86.0 (1.9)	106.5 (6.4)	0.002
BMI	29.8 (0.5)	29.8 (0.4)	28.9 (0.3)	28.4 (0.04)	0.035
Discrete variables	**N (%)**				
BMI Category:					
Underweight: <18.5	3 (0.6)	5 (1.1)	7 (2.3)	6 (1.6)	0.026
Normal range: 18.5-24.6	83 (28.1)	84 (21.0)	112 (22.8)	125 (26.5)	
Overweight: 25-30	107 (28.7)	163 (36.1)	192 (38.0)	224 (38.7)	
Obese: >30	167 (42.6)	208 (41.8)	218 (36.9)	215 (33.2)	
Gender					
Male	79 (18.4)	215 (45.2)	300 (54.9)	376 (64.9)	<0.0001
Female	283 (81.6)	246 (54.8)	232 (45.1)	198 (35.1)	
Smoking					
Never	162 (45.6)	239 (55.7)	275 (52.8)	313 (57.0)	0.0031

Former	97 (27.6)	125 (29.7)	154 (30.7)	163 (28.5)	
Current	103 (26.8)	97 (14.6)	103 (16.5)	98 (14.5)	
Spirometry Grade Classificaitons:					
Normal airflow	183 (50.1)	269 (50.1)	354 (67.0)	390 (68.3)	<0.0001
Airflow restriction	122 (29.8)	125 (29.7)	85 (14.1)	95 (14.8)	
Airway obstruction	55 (20.1)	67 (16.9)	90 (18.9)	86 (17.0)	
GOLD:					
Normal	305 (80.0)	394 (85.9)	444 (81.1)	485 (83.1)	0.35
Airflow obstruction	55 (20.1)	67 (14.1)	85 (18.9)	86 (16.9)	

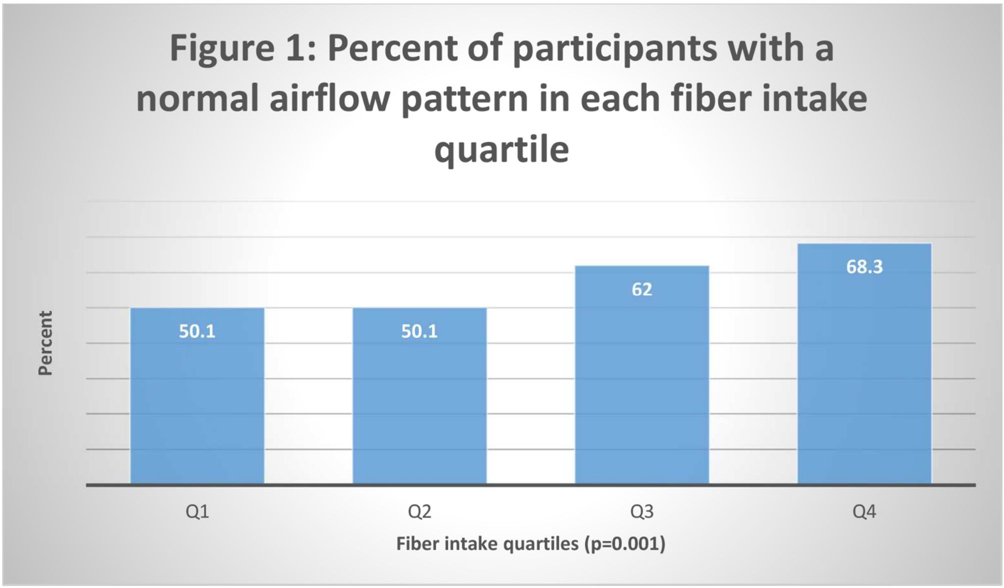
Table 3: Results of Multivariable Regression Models of Fiber Intake Quartiles and Lung Function Measurements*

Daily Fiber Intake Quartile (grms/d)	FEV_1 (mL)		FVC (mL)		% Pred FEV_1		% Pred FVC	
	β	p-value	β	p-value	β	p-value	β	p-value
<10.75	Reference							
10.75≤13.46	36.8	0.28	25.3	0.45	1.4	0.23	0.75	0.34
13.46≤17.5	82.3	0.04	115.2	0.003	2.7	0.03	2.7	0.003
≥17.5	81.7	0.05	128.9	0.01	2.4	0.07	2.8	0.02
Daily Fruit/veg/ legume Intake (cups/day)	**FEV_1 (mL)**		**FVC (mL)**		**% Pred FEV_1**		**% Pred FVC**	
	β	p-value	β	p-value	β	p-value	β	p-value
<1.69	Reference							
1.69-<2.31	68.1	0.06	46.3	0.32	1.9	0.07	1.0	0.32
2.31-<3.07	28.0	0.47	75.1	0.18	0.96	0.43	1.5	0.23
≥3.07	106.7	0.001	127.0	0.006	3.3	0.0009	2.8	0.007

*Models adjusted for age, BMI, energy intake, smoking status, height, gender, socioeconomic status, CRP, and intakes of alpha-tocopherol, alpha-carotene, beta-carotene, beta-cryptoxanthin, lycopene, luten+zeaxanthin, vitamin C, and cured meat.

Figure Legend: Figure 1 Percent of participants with a normal airflow pattern according to the spirometry grading classification by each fiber intake quartile. Fiber intake key: Q1=<10.75 g/day, Q2=10.75-<13.46 g/day, Q3=13.46-17.5 g/day, Q4=>17.5 g/day

Figure Legend: Figure 2 Percent of participants with a restrictive airflow pattern according to the spirometry grading classification by each fiber intake quartile. Fiber intake key: Q1=<10.75 g/day, Q2=10.75-<13.46 g/day, Q3=13.46-17.5 g/day, Q4=>17.5 g/day



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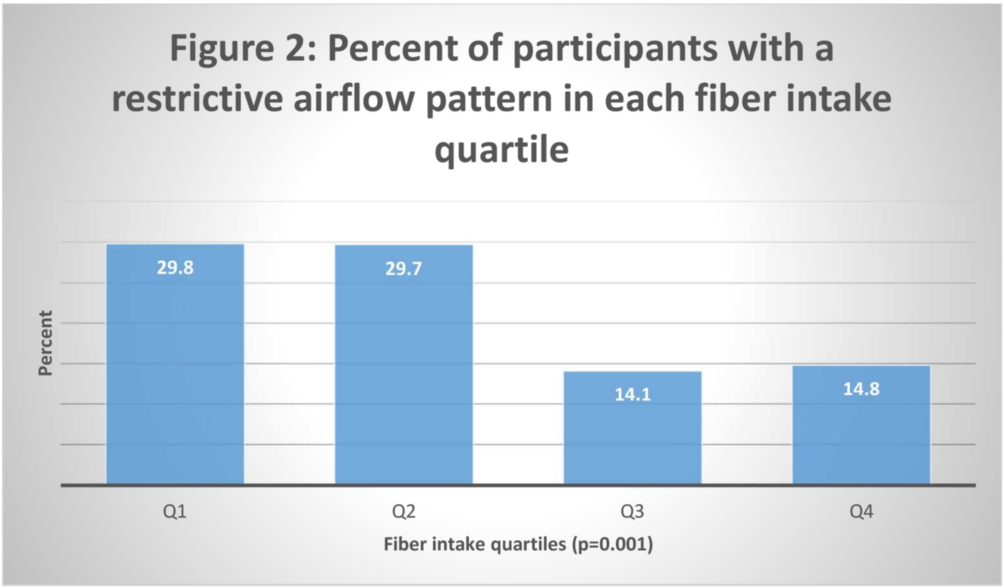

Figure 2 Percent of participants with a restrictive airflow pattern according to the spirometry grading classification by each fiber intake quartile. Fiber intake key: Q1=<10.75 g/day, Q2=10.75-<13.46 g/day, Q3=13.46-17.5 g/day, Q4=>17.5 g/day

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