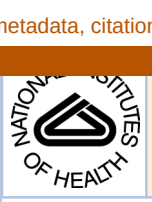

Published in final edited form as:

Psychosom Med. 2013 October ; 75(8): 737–743. doi:10.1097/PSY.0b013e3182a15672.

The association of depressive symptoms and pulmonary function in healthy adults

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Abstract

Objective—Chronic lung disease is exacerbated by comorbid psychiatric issues and treatment of depression may improve disease symptoms. We sought to add to the literature as to whether depression is associated with pulmonary function in healthy adults.

Methods—In 2,551 healthy adults from New York State, USA, we studied the association of depression via the Center for Epidemiologic Studies Depression scale (CES-D) score and forced expiratory volume (FEV_1) and forced vital capacity (FVC) using general linear models and a cross sectional design.

Results—We identified statistically significant inverse trends in FEV_1, FVC, FEV_1% and FVC% by CES-D category especially in ever smokers and men. When adjusted for covariates, the difference in FEV_1 and FEV_1% for smokers with >18.5 lifetime pack years from CES-D score 0-3 to ≥16 (depressed) is approximately 0.25 L and 5.0%; adjusted *P* for trend are <0.001 and 0.019, respectively. In men, we also observed statistically significant inverse trends in pulmonary function with increasing CES-D.

Conclusions—We identified an inverse association of depressive symptoms and pulmonary function in healthy adults especially in men and individuals with a heavy smoking history. Further

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Conflicts of Interest: None

studies of these associations are essential for the development and tailoring of interventions for the prevention and treatment of chronic lung disease.

Keywords

pulmonary disease; chronic lung disease; depression; respiratory function tests

INTRODUCTION

The relationship between mental health and respiratory health is well recognized [1-3]; however the direction and exact nature of these complex associations are unknown. While stressful stimuli can have short-term and measurable influence specifically on the airways [3-5]; less is known about the long-term influence of mental health on airways, pulmonary function, and the complex phenotypes of asthma and COPD.

In individuals already diagnosed with chronic lung disease, there is evidence that depressive symptoms in particular are a direct result of chronic lung disease. Here, biologic changes due to the disease process may be implicated in development of depressive symptoms. Depression may however also play an earlier role in the disease process, detectable before the onset of chronic lung disease, but also may be intrinsically linked with smoking behavior [6]. Improving both the psychological and physical well-being of individuals already diagnosed with chronic lung disease may potentially improve quality of life and outcomes [7-9].

To date, there are no large and comprehensive studies that have reported on the association of mental health and pulmonary function before diagnosis of chronic lung disease in attempts to tease out the effects of smoking. Therefore, we examined the association of pulmonary function and depressive symptoms measured via CES-D score in a sample of adults never diagnosed with chronic lung disease. Due to the association of depression and smoking, we hypothesized *a priori* that smoking modifies the association of depressive symptoms and reduced pulmonary function.

METHODS

Study population

As previously described [10], we randomly selected participants aged 35-79 from the general population in Erie and Niagara counties in western New York State between 1996 and 2000 for a cross-sectional study, with the goal of investigating several potential determinants of pulmonary function. Of our original sample (n=4,065), we excluded individuals who had missing or unacceptable pulmonary function tests (n=1,049), missing CES-D questionnaire (n=91), and those who have ever been diagnosed by a physician with fibrosis (n=8) or chronic airflow limitation (asthma, COPD, chronic bronchitis or emphysema) (n = 366), resulting in 1,276 men and 1,275 women for analysis. The study was approved by the University at Buffalo Health Sciences Institutional Review board and all participants provided written informed consent.

Pulmonary Function Tests

Trained personnel performed spirometry according to American Thoracic Society recommendations as previously reported [11]. We first performed two to three slow practice maneuvers followed by at least three but no more than eight maneuvers, and used the best of three acceptable maneuvers for study. Approximately 6.9% (n=223) of the sample who had a pulmonary function test performed was excluded from this study due to unacceptable tests.

To obtain percent predicted values for FEV_1 and FVC (FEV_1% and FVC%) we used NHANES data to adjust for sex, age, height and race/ethnicity [12].

Center for Epidemiologic Studies Depression Scale Questionnaire (CES-D)

The CES-D questionnaire measures self-reported depressive symptoms experienced by a person during the previous week [13]. Each question is scored 0-3 based on the person's response, resulting in a possible score range of 0-60. The person is considered depressed if his or her score is ≥16. This screening tool has been extensively evaluated for validity and reliability [14, 15].

Measurement of other relevant covariates

During the study visit, we collected data on demographics, medical history and an array of other behavior variables including lifetime smoking data. A computer-assisted interview was used to assess cumulative lifetime exposure to smoking (pack-years); from this, we classified individuals as current, former or never smokers (less than 100 cigarettes smoked during lifetime). Physical measurements were taken using standard protocol and include height, weight, waist circumference and hip circumference. For abdominal height, interviewers used a Holtain-Kahn abdominal caliper and measured the sagittal diameter of the participant in the supine position [16]. Serum beta cryptoxanthin was measured by high-pressure liquid chromatography on a Shimadzu LC-7A device with SPD-M6A photodiode array (Shimadzu Scientific Instruments, Inc., Braintree, MA) and expressed as μg/ml [17]. An automated differential blood cell count was determined at the Kaleida/Millard Fillmore Hospital Center for Laboratory Medicine in Buffalo, New York, using a Coulter Counter (Beckman Coulter, Inc., Fullerton, CA).

Statistical analyses

We computed descriptive statistics for all relevant variables to characterize the sample, and used student's t-tests and chi-squared tests to examine differences between measurements collected for men and women as appropriate. Spearman correlation coefficients were estimated to examine linear associations between continuous measures of CES-D and pulmonary function measures.

We analyzed trends in FEV_1, FVC, FEV_1%, and FVC% across four strata defined by CES-D score (0-3, 4-8, 9-15, and ≥16) using general linear models that were adjusted for the following covariates as appropriate because they are associated with pulmonary function in this sample: age, sex, height, race/ethnicity (white, African American, and Hispanic), education, smoking status (ever/never), lifetime number of pack-years, abdominal height (cm), and serum beta-cryptoxanthin (positively associated with pulmonary function), and eosinophil count for FEV_1 and FEV_1% only (inversely associated with FEV_1 [17-19]. Since FEV_1% and FVC% predicted values are already adjusted for age, sex, height and race/ethnicity, we did not adjust for these covariates in these respective models. We assessed significance using *P*-values for trend where CES-D is included in linear models as a continuous variable (instead of categories), where any *P*-value <0.050 was considered statistically significant.

We decided *a priori* to examine the association by stratifying by smoking status and sex to analyze potential effect modification of the association of pulmonary function and depressive symptoms by smoking status and sex. To test interaction hypotheses, we created multiplicative interaction terms for lifetime pack years of smoking × CES-D score and sex × CES-D score. For tests of multiplicative interaction, we considered *P*-values <0.10 statistically significant. For all analyses, we used the SAS statistical software package (SAS, version 9.2; SAS; Cary, NC).

RESULTS

Table 1 shows descriptive characteristics of the study population, including means for CES-D and pulmonary function measures stratified by sex. The mean age of participants in our sample is 57.3 years (standard deviation (SD)=11.5 years) and 60.4 years (SD=11.9 years) for women and men, respectively. Approximately 7% of our sample is African-American and 0.6% is Hispanic. FEV_1 and FVC values are higher for men; however in comparison to US reference values (based on the average level of lung function observed in healthy nonsmoking persons of the same age, sex, height and race/ethnicity), FEV_1% predicted and FVC% predicted values are higher in women (P<0.001). More women in our sample are current smokers, but men have a higher lifetime exposure to cigarettes as measured by pack years (P<0.001). Mean BMI values for women and men are 27.8 kg/m^2 (SD=6.0 kg/m^2) and 28.5 kg/m^2 (SD=4.5 kg/m^2), respectively. Women in this sample are more likely to have CES-D scores ≥16, indicative of depression; 13.8% of women had scores ≥16 versus 10.5% of men. Thirty nine percent of women and 45% of men had CES-D scores in the lowest category (0-3). Spearman correlation coefficients between CES-D score and pulmonary function values were approximately −0.18 for FEV_1 and FVC, and −0.07 for both FEV_1% and FVC%, and all are statistically significant (data not shown).

Table 2 shows trends in adjusted mean FEV_1 and FVC by CES-D category in ever smokers, split according to the median value of lifetime pack years of smoking of 18.5 pack years, and never smokers separately. The interaction term for lifetime pack years × CES-D is statistically significant for FEV_1 (interaction P-value=0.052) only. In both smoking groups, the inverse trends in FEV_1, FVC and FEV_1% were statistically significant; the lowest values of pulmonary function are observed in the groups with the highest values of CES-D (all P-for trend <0.035). We observed marginally significant trends in FVC% in ever smokers; P-values for trend were approximately 0.050 in both groups. In never smokers, we report a statistically significant inverse trend in FVC (L) only (P-for trend=0.038) across strata of CES-D scores.

With regard to magnitude of differences in the lowest versus the highest categories of CES-D, in the group of smokers with more than 18.5 lifetime pack years, the difference in FEV_1 between CES-D score 0-3 and ≥16 (depressed) was 0.25 L, the difference in FVC was 0.23 L, and the FEV_1% difference was 5.0% (Table 2, Model 2). For smokers with less than 18.5 lifetime pack years of smoking, the differences were similar in magnitude; we observed a 0.19 L difference in FEV_1, a 0.20 difference in FVC, and a 6% difference in FEV_1% between the highest and lowest categories defined by CES-D score.

When we modeled the continuous CES-D variable (instead of using four categories) in linear models predicting differences in pulmonary function, we observed beta coefficients of −0.01 (standard error=0.004) for the models of FEV_1 and FVC analyzed in liters. These estimates suggest that for every unit increase in CES-D score, FEV_1 and FVC is approximately 0.01 L lower. Similarly, in the FEV_1 percent predicted model, we estimated a beta coefficient of −0.29 (standard error=0.12), suggesting that for every unit increase in CES-D score, FEV_1% is approximately 0.29% lower (data not shown).

The interaction between sex and CES-D score was significant for FEV_1 (P=0.003), FVC (P=0.008) and FEV_1% (P=0.048); therefore we present results stratified by sex in **Table 3**. **Table**In men, inverse trends in the fully-adjusted models for all measures of pulmonary function analyzed were statistically significant (all P for trend<0.004), with differences between CES-D category 0-3 and ≥16 category of approximately 0.20 L. The difference in FEV_1% from CES-D category 0-3 and ≥16 category was 4.4%. In women, FVC (L) was the

only pulmonary function measure that reached statistical significance for linear trends across CES-D categories (*P* for trend=0.022).

DISCUSSION

We investigated the relation of pulmonary function measures and depressive symptoms measured by CES-D score in a cross-sectional study of healthy adults. Our results suggest that ex sex independently modifies the association of FEV_1, FVC and FEV_1%; we observed the strongest inverse associations between depressive symptoms and pulmonary function in men. The statistically significant interaction we observed for FEV_1 according to categories of lifetime pack years along with the differences in the differences in FEV_1 across CES-D categories suggests that depression is particularly associated with FEV_1 in those with more than 18 pack years of smoking. Men and smokers with more than 18.5 pack years and the highest CES-D scores had the lowest FEV_1, FVC, FEV_1% and FVC% values, all of which reached statistical significance with the exception of FVC%. Our findings support our *a priori* hypothesis that depressive symptoms are inversely associated with pulmonary function in healthy adults. However, in our sample, there were no associations of pulmonary function and depressive symptoms among women and weaker evidence of an association with FVC among never smokers and in women.

Candidate biologic mechanisms for the depression-airway reactivity association are currently under study and include inflammatory and immune as well as cholinergic/vagal mechanisms [5, 20]. Whether these mechanisms, largely explored in the context of adult and childhood asthma and reflective of short-term response, translate to long-term periods of depression is yet to be explored.

Smoking plays an important role in this association of CES-D and FEV_1, since we observed the largest differences in FEV_1 across CES-D categories in smokers compared to never smokers. Depressive symptoms may be related to decreased pulmonary function due to smoking behavior [21]. Individuals with depression are more likely to smoke and smoking behavior has been linked to chronic pulmonary diseases and decreased pulmonary function [7, 22]. According to a nationally representative survey, the prevalence of smoking among the mentally ill is nearly double that of the general United States population, where nearly one-third of smokers had met ICD-10 criteria for a mental disorder [23]. Our finding of smoking status as a statistically significant effect modifier (for FEV_1) implicates smoking, and this is not surprising given that smoking is associated with both pulmonary function and mental health.

To our knowledge, five large epidemiologic studies to date have attempted to examine associations between lung function and depressive symptoms. The first two studies focused on risk and prevalence of depression in the presence of chronic lung disease (versus quantitative pulmonary function measures). Findings from Bisschop et al suggest that chronic lung disease is associated with increased risk of depression over 3 years of follow-up; however they reported no association of incident lung disease and CES-D [2]. These findings may suggest that the association of chronic lung disease and depression is more important over a longer time period, which is in agreement with our evidence for an association in “healthy” adults of depression and pulmonary function measures earlier in the CLD disease process. Another study showed that chronic lung disease is associated with significantly higher prevalence of depressed mood measured via CES-D [24].

The third, a study of NHANES data, reported an association of obstructive lung function and worse mental health status; however this study did not have the data available to examine smoking in the relationship between lung function and mental health [25]. Two subsequent

studies have assessed lung function and mental health [26, 27] but only one was performed in a sample representative of the general population [27]; this study reported that asthma and chronic bronchitis were associated with mental health problems but objective lung function assessed by spirometry was only associated with anxiety [27]. The final study was conducted in a population of adults who had served in Vietnam [26]; generalized anxiety disorder and major depressive disorder was associated with poor lung function; however, only generalized anxiety disorder remained significant after adjustment for covariates.

Other investigators have reported an increased prevalence of depression in COPD patients [7, 28] and that symptoms of depression are associated with decreased pulmonary function values, specifically FEV_1 [8]. Similar to our study sample where we have a higher prevalence of depression reported among women never diagnosed with COPD, one study reported that female COPD patients were more likely to be depressed and exhibit depressive symptoms than men [21, 29, 30], which indicates that women may be at even greater risk of depression in the context of COPD. In addition, among smokers, women were more likely to meet the criteria for mental illness than men [23]. We observed an interaction between sex and CES-D, which may be due to the smaller differences between the lowest and highest CES-D categories in women. While the trends in women did not reach statistical significance for FEV_1 or FEV_1%, the trends for FVC (L) were statistically significant. This finding may be due to the increased prevalence of depressive symptoms in women in our sample.

Our study differs from previous studies on this topic because many previous studies focused on participants diagnosed with COPD [8, 21, 29-31] whereas we focused on a large sample of healthy adults who have never been diagnosed with chronic lung disease. In addition, sample size is a limitation for many previous studies, with most studies including fewer than 500 participants. Another difference between our study and others in the literature is the measurement of depressive symptoms. We used the CES-D questionnaire, whereas other measurement tools used in previous literature include the Beck Depression Inventory [29], the Hospital Anxiety and Depression Scale [30, 32] or the 15-item Geriatric Depression Score [8]. The CES-D questionnaire has been used across all age groups and has proven to be valid and reliable for use in the general population [14, 15].

A major strength of our study lies in the available study population, a large sample of healthy adults that includes a detailed ascertainment of lifetime smoking history. Standardized anthropometric and pulmonary function measures and the use of the validated CES-D questionnaire to assess depressive symptoms provide much strength to this study. With these standardized quantitative measures, we had the ability to adjust for a number of factors that are known to influence pulmonary function.

Previously, no study has used a large, population-based sample to study the association between depression and pulmonary function, nor has there been a focus on healthy individuals never diagnosed with chronic lung disease. By studying this association in healthy individuals, we are better able to understand associations between depression and pulmonary function prior to diagnosis with chronic lung disease. This understanding may provide a novel intervention opportunity with the aim of reducing pulmonary function decline or progression of chronic lung disease before irreversible manifestations occur.

The cross-sectional nature of our study is a limitation because of the lack of temporality. In addition, our sample may contain some individuals with undiagnosed chronic lung disease, which may potentially strengthen the inverse associations seen between pulmonary function and depressive symptoms. In our study sample, 382 of 2,551 (15%) had an FEV_1/FVC of 70% or lower. In sensitivity analyses where we excluded individuals with a FEV_1/FVC

<70% in an attempt to exclude individuals with undiagnosed pulmonary disease, the results are essentially unchanged. The association of CES-D is still most significant for individuals who have ever smoked and the FEV_1 difference between the lowest CES-D category (0-3) and highest (≥16) is approximately 0.23 L and 5.6%. Interestingly, when individuals with FEV_1/FVC <70% are excluded, all of the trends in the association of CES-D and pulmonary function become more statistically significant in women (data not shown). In addition, since spirometry is effort-dependent, depressed participants may not have performed the tests with maximum effort, which may contribute to the observed associations.

The fact that the associations between CES-D and pulmonary function remain even after adjustment for abdominal obesity, a confounding variable, further supports the merit of an association; however this association requires further study.

Participants with low pulmonary function values may be more likely to indicate experiencing a symptom of depression that is actually a result of underlying disease [31, 33, 34], making interpretation of findings difficult. Our aforementioned sensitivity analysis that excluded individuals with FEV_1/FVC <70% however further supports the hypothesis that the association of CES-D and pulmonary function may be mitigated through smoking behavior rather than the disease process itself.

Future studies into these associations should be longitudinal in design so the mechanism of chronic lung disease progression can be determined in regards to smoking behavior and depression. We know that there is a causal relationship between smoking and COPD [7], but the role of depression in this etiological relationship has never been sufficiently illustrated. Is this association a ‘feedback loop’ as others suggest [34] or is depression the underlying cause of disease in these individuals, predating even smoking behavior?

Overall, our results suggest that depression may play an even earlier role in the chronic lung disease process, and that sex and smoking play a role. If this association is replicated in other studies, it would be very interesting to evaluate whether improvement in mental status would translate into improvement in pulmonary function.

Acknowledgments

This work was supported in part by a grant from the American Lung Association (to Holger Schünemann, MD, PhD), the National Institute on Alcohol Abuse and Alcoholism at the National Institutes of Health (P50 AA09802) (to Jo Freudenheim, PhD, and Maurizio Trevisan, MD) and the National Institute for Occupational Safety and Health (contract number 200-2003-01580). The authors thank the personnel at the Center for Preventive Medicine at the University at Buffalo for their contribution to the study. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

Funding: This work was supported in part by a grant from the American Lung Association to Holger Schünemann, the National Institute on Alcohol Abuse and Alcoholism at the National Institutes of Health (grant P50 AA09802), and the National Institute for Occupational Safety and Health (contract number 200-2003-01580).

Abbreviations

CES-D	Center for Epidemiologic Studies Depression scale
COPD	Chronic obstructive pulmonary disease
FEV_1	forced expiratory volume in 1 second
FVC	forced vital capacity
QOL	quality of life

SD standard deviation

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Table 1

Descriptive Characteristics, Mean (SD) or n (%), of Study Participants in Erie and Niagara Counties, Western New York State, 1996-2000.

Characteristic	Total (n=2,551)	Men (n=1,276)	Women (n=1,275)	*P*-value[a]
Age (yr)	58.8 (11.8)	60.4 (11.9)	57.3 (11.5)	<0.001
Age group				
≤40	170 (6.7)	85 (6.7)	85 (6.7)	
41-50	605 (23.7)	259 (20.3)	346 (27.1)	
51-60	545 (21.4)	229 (18.0)	316 (24.8)	<0.001
61-70	726 (28.5)	385 (30.2)	341 (26.8)	
> 70	505 (19.8)	318 (24.9)	187 (14.7)	
Race/ethnicity				
Hispanic	15 (0.6)	10 (0.8)	5 (0.4)	
African American	179 (7.0)	92 (7.2)	87 (6.8)	0.40
White	2,357 (92.4)	1,174 (92.0)	1,183 (92.8)	
Education				
≤High school/GED	1,068 (42.1)	482 (38.1)	586 (46.2)	
College <4 yrs	725 (28.6)	369 (29.2)	356 (28.1)	<0.001
College ≥4 yrs	742 (29.3)	415 (32.8)	327 (25.8)	
Smoking status				
Current	336 (13.2)	157 (12.3)	179 (14.1)	
Former	1,105 (43.5)	657 (51.7)	448 (35.3)	<0.001
Never	1,102 (43.3)	458 (36.0)	644 (50.7)	
Lifetime pack-years of smoking	13.24 (19.5)	17.53 (22.2)	8.98 (15.1)	<0.001
Lifetime pack-years of smoking among smokers	23.4 (20.8)	27.5 (22.4)	18.2 (17.2)	<0.001
BMI (kg/m^2)	28.1 (5.3)	28.5 (4.5)	27.8 (6.0)	0.002
Abdominal height (cm)	21.3 (3.5)	22.2 (3.2)	20.3 (3.5)	<0.001
Waist circumference (cm)	92.5 (14.6)	99.2 (12.1)	85.8 (13.9)	<0.001
CES-D score	7.0 (7.5)	6.5 (7.2)	7.5 (7.7)	0.001
CES-D score category				
0 – 3	1075 (42.1)	574 (45.0)	501 (39.3)	
4 – 8	684 (26.8)	346 (27.1)	338 (26.5)	0.003
9 – 15	482 (18.9)	222 (17.4)	260 (20.4)	
≥ 16	310 (12.2)	134 (10.5)	176 (13.8)	
FEV_1 (L)	2.95 (0.81)	3.32 (0.83)	2.57 (0.57)	<0.001
FVC (L)	3.83 (0.99)	4.35 (0.97)	3.30 (0.69)	<0.001
FEV_1/FVC	0.77 (0.08)	0.76 (0.08)	0.78 (0.07)	<0.001
FEV_1%[b]	99.2 (17.5)	97.3 (18.4)	101.1 (16.3)	<0.001
FVC%[b]	99.1 (15.8)	96.7 (16.1)	101.5 (15.2)	<0.001

Abbreviations: CES-D = Center for Epidemiologic Studies Depression scale; FEV_1 = forced expiratory volume; FVC = forced vital capacity; SD = standard deviation.

[a] Student's t-tests or chi-squared tests for differences by sex.

[b] FEV_1% and FVC% calculated using U.S. reference values [12].

Table 2

Adjusted Mean Levels of Pulmonary Function by Pack Years of Smoking and CES-D Score, Mean (SE), in Erie and Niagara Counties, Western New York State, 1996-2000.

		>18.5 lifetime pack-years of smoking			≤18.5 lifetime pack-years of smoking			Never smokers		
Pulmonary function	**CES-D category**	**N**	**Model 1[a]**	**Model 2[b]**	**N**	**Model 1[a]**	**Model 2[b]**	**N**	**Model 1[a]**	**Model 2[b]**
FEV_1,[d] L	0 – 3	278	2.85 (0.03)	2.90 (0.04)	310	3.09 (0.03)	3.08 (0.03)	482	3.02 (0.02)	3.02 (0.02)
	4 – 8	200	2.77 (0.04)	2.84 (0.05)	178	3.05 (0.03)	3.08 (0.04)	302	3.02 (0.02)	3.08 (0.03)
	9 – 15	130	2.69 (0.05)	2.70 (0.07)	144	3.01 (0.04)	3.07 (0.05)	203	3.01 (0.03)	3.03 (0.04)
	≥ 16	105	2.68 (0.06)	2.65 (0.07)	88	2.85 (0.05)	2.89 (0.06)	115	2.91 (0.04)	2.96 (0.05)
	P-value for trend		<0.001	<0.001		<0.001	0.018		0.008	0.14
	interaction *P*-value[f]			0.052						
FVC, L	0 – 3	278	3.84 (0.04)	3.92 (0.05)	310	3.93 (0.03)	3.95 (0.04)	482	3.86 (0.02)	3.88 (0.03)
	4 – 8	200	3.76 (0.05)	3.84 (0.06)	178	3.95 (0.04)	4.01 (0.05)	302	3.83 (0.03)	3.91 (0.04)
	9 – 15	130	3.67 (0.06)	3.70 (0.07)	144	3.85 (0.05)	3.93 (0.06)	203	3.83 (0.04)	3.84 (0.05)
	≥ 16	105	3.71 (0.06)	3.69 (0.08)	88	3.67 (0.06)	3.74 (0.08)	115	3.69 (0.05)	3.77 (0.07)
	P-value for trend		0.014	<0.001		<0.0001	0.014		0.003	0.038
	interaction *P*-value[f]			0.22						
FEV_1%[d,e]	0 – 3	278		94.0 (1.42)	310		102.5 (1.10)	482		103.3 (0.84)
	4 – 8	200		91.4 (1.72)	178		102.9 (1.43)	302		105.3 (1.12)
	9 – 15	130		88.5 (2.23)	144		103.0 (1.64)	203		103.8 (1.33)
	≥ 16	105		89.0 (2.51)	88		96.5 (2.17)	115		101.3 (1.81)
	P-value for trend			0.019			0.035			0.20
	interaction *P*-value[f]			0.19						
FVC%[e]	0 – 3	278		97.0 (1.18)	310		101.3 (1.03)	482		102.4 (0.81)
	4 – 8	200		94.5 (1.43)	178		103.3 (1.35)	302		103.5 (1.09)
	9 – 15	130		92.8 (1.84)	144		101.6 (1.54)	203		101.2 (1.28)
	≥ 16	105		94.3 (2.08)	88		96.8 (2.04)	115		99.7 (1.73)

		>18.5 lifetime pack-years of smoking			≤18.5 lifetime pack-years of smoking			Never smokers		
Pulmonary function	**CES-D category**	**N**	**Model 1[a]**	**Model 2[b]**	**N**	**Model 1[a]**	**Model 2[b]**	**N**	**Model 1[a]**	**Model 2[b]**
	P-value for trend			0.052			0.047			0.066
	interaction *P*-value[f]			0.68						

Abbreviations: CES-D = Center for Epidemiologic Studies Depression scale; FEV_1 = forced expiratory volume; FVC = forced vital capacity; SE = standard error.

[a] Model 1: General linear model adjusted for age, height, race and sex.

[b] Model 2: General linear model adjusted for Model 1 variables plus abdominal height, education and serum beta cryptoxanthin.

[d] FEV_1 and FEV_1% were additionally adjusted for eosinophil count.

[e] FEV_1% and FVC% were analyzed without adjustments for age, sex, height, and race.

[f] *P*-values represent multiplicative interaction terms for lifetime pack years and quantitative values of CES-D score.

Table 3

Adjusted Mean Levels of Pulmonary Function by Sex and CES-D Score Categories, Mean (SE), in Erie and Niagara Counties, Western New York State, 1996-2000.

		Male			Female		
Pulmonary function	**CES-D category**	**N**	**Model 1[a]**	**Model 2[b]**	**N**	**Model 1[a]**	**Model 2[b]**
FEV_1[d]	0 – 3	574	3.40 (0.02)	3.45 (0.03)	501	2.59 (0.02)	2.56 (0.02)
	4 – 8	346	3.34 (0.03)	3.45 (0.04)	338	2.57 (0.02)	2.58 (0.03)
	9 – 15	222	3.27 (0.04)	3.37 (0.05)	260	2.56 (0.02)	2.56 (0.03)
	≥ 16	134	3.11 (0.05)	3.26 (0.06)	176	2.50 (0.03)	2.49 (0.04)
	P-value for trend		<0.001	0.001		0.010	0.058
	interaction *P*-value[f]			0.003			
FVC	0 – 3	574	4.42 (0.03)	4.53 (0.03)	501	3.32 (0.02)	3.30 (0.03)
	4 – 8	346	4.35 (0.04)	4.51 (0.05)	338	3.32 (0.02)	3.34 (0.03)
	9 – 15	222	4.30 (0.05)	4.41 (0.06)	260	3.28 (0.03)	3.28 (0.04)
	≥ 16	134	4.14 (0.06)	4.32 (0.08)	176	3.22 (0.04)	3.21 (0.04)
	P-value for trend		<0.001	<0.001		0.010	0.022
	interaction *P*-value[f]			0.008			
$FEV_1\%$[d,e]	0 – 3	574		99.0 (0.86)	501		101.2 (0.86)
	4 – 8	346		98.7 (1.15)	338		102.4 (1.08)
	9 – 15	222		96.3 (1.48)	260		102.2 (1.22)
	≥ 16	134		94.6 (1.97)	176		99.3 (1.53)
	P-value for trend			0.004			0.30
	interaction *P*-value[f]			0.048			
FVC%[e]	0 – 3	574		98.9 (0.76)	501		101.8 (0.82)
	4 – 8	346		98.3 (1.02)	338		103.3 (1.03)
	9 – 15	222		96.3 (1.31)	260		101.7 (1.16)
	≥ 16	134		95.4 (1.75)	176		100.0 (1.45)
	P-value for trend			0.004			0.14

Pulmonary function	CES-D category	Male N	Male Model 1[a]	Male Model 2[b]	Female N	Female Model 1[a]	Female Model 2[b]
	interaction *P*-value[f]			0.16			

Abbreviations: CES-D = Center for Epidemiologic Studies Depression scale; FEV_1 = forced expiratory volume; FVC = forced vital capacity; SE = standard error.

[a] Model 1: General linear model adjusted for age, height, and race.

[b] Model 2: General linear model adjusted for Model 1 variables plus smoking status, lifetime pack years, abdominal height, education, and serum beta cryptoxanthin.

[d] FEV_1 and FEV_1% were also adjusted for eosinophil count.

[e] FEV_1% and FVC% were analyzed without adjustments for age, height, and race.

[f] *P*-values represent multiplicative interaction terms for sex and CES-D score.