CHRONIC OBSTRUCTIVE PULMONARY DISEASE

Lung function and mortality in the United States: data from the First National Health and Nutrition Examination Survey follow up study

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Background: A study was undertaken to define the risk of death among a national cohort of US adults both with and without lung disease.
Methods: Participants in the first National Health and Nutrition Examination Survey (NHANES I) followed for up to 22 years were studied. Subjects were classified using a modification of the Global Initiative for Chronic Obstructive Lung Disease criteria for chronic obstructive pulmonary disease (COPD) into the following mutually exclusive categories using the forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), FEV_1/FVC ratio, and the presence of respiratory symptoms: severe COPD, moderate COPD, mild COPD, respiratory symptoms only, restrictive lung disease, and no lung disease. Proportional hazard models were developed that controlled for age, race, sex, education, smoking status, pack years of smoking, years since quitting smoking, and body mass index.
Results: A total of 1301 deaths occurred in the 5542 adults in the cohort. In the adjusted proportional hazards model the presence of severe or moderate COPD was associated with a higher risk of death (hazard ratios (HR) 2.7 and 1.6, 95% confidence intervals (CI) 2.1 to 3.5 and 1.4 to 2.0), as was restrictive lung disease (HR 1.7, 95% CI 1.4 to 2.0).
Conclusions: The presence of both obstructive and restrictive lung disease is a significant predictor of earlier death in long term follow up.

Chronic obstructive pulmonary disease (COPD) is an important cause of morbidity and mortality in the United States.[1] The diagnosis of obstructive lung disease has traditionally depended on the presence of symptoms such as chronic cough or chronic sputum production.[2] New international guidelines for the diagnosis of obstructive lung disease depend almost exclusively on measured lung function to diagnose and classify disease.[3] Lung function is not routinely measured in most patients, and a significant proportion of the population with abnormal lung function has no diagnosed lung disease.[4]

Impaired lung function has previously been shown to predict mortality, although most previous studies have not used clinical criteria to classify COPD, and none to our knowledge have looked at the effect of restrictive lung disease on mortality.[5–11]

We applied spirometric criteria for the diagnosis of obstructive and restrictive lung disease to a cohort of 5542 subjects in whom pulmonary function measurements had been performed as part of the First National Health and Nutrition Examination Survey (NHANES I). We searched the NHANES I follow up database for death in the follow up period of up to 22 years and determined the significant predictors of death in this cohort.

METHODS

The National Center for Health Statistics conducted NHANES I from 1971 to 1975. This was a survey of a probability sample of the civilian non-institutionalised population of the United States.[12 13] Follow up surveys of the adult participants (aged 25–74 years) in NHANES I were undertaken in 1982–4, 1986, 1987, and 1992.[14–17] Data collected on participants included hospitalisation records, vital status, and death certificates (for those who had died). Up to 1992, 96% of the original cohort had been successfully traced and death certificates were available for 98% of the 4604 documented deaths.[15]

Questionnaire data

Participants in NHANES I completed an extensive questionnaire that included age, race, sex, and education level. Participants were classified as having ⩽12 years or ⩾13 years of education. A nationally representative subset of participants completed a cardiorespiratory module that included a series of questions about the presence of respiratory symptoms and the diagnosis of respiratory disease. Pulmonary symptoms included in the analysis (used to define an asymptomatic subset of the population to calculate equations for lung function and define a subset of the cohort with only respiratory symptoms) were cough (defined as a positive response to "Have you ever had a cough first thing in the morning in the winter?" or "Have you ever had a cough first thing in the morning in the summer?"), sputum, (defined as a positive response to "Have you ever had any phlegm from your chest first thing in the morning in the winter?" or "Have you ever had any phlegm from your chest first thing in the morning in the summer?"), and wheeze (defined as a positive response to "Have you ever had wheezy or whistling sounds in your chest?"). Participants were also asked whether they had physician diagnosed chronic bronchitis (non-allergic), emphysema, or asthma.

Complete smoking histories were obtained for all participants. Current smokers were defined as those who reported the use of cigarettes, cigars, or pipes at the time of the survey, and former smokers were those who reported any prior use of cigarettes (at least 100 cigarettes), cigars (at least 50), or pipes (at least three packages of tobacco), but no current use. Long term "intensity of use" data were available only for cigarettes. Pack-years of cigarette use were calculated by multiplying the average number of cigarettes smoked daily by the number of years smoked and dividing the product by 20. Former cigarette

Table 1 Demographic characteristics of participants included in the analysis

	N	Severe COPD (%)**	Moderate COPD (%)	Mild COPD (%)	Symptoms only (%)	Restrictive disease (%)	Death
Age							
25–39	1903	0.2	2.8	4.0	19.2	6.5	3.8
40–49	1171	0.8	5.9	7.0	18.7	7.9	11.8
50–59	1168	2.6	10.4	9.5	12.8	11.6	26.4
60–69	967	3.7	10.7	12.7	12.5	11.4	53.6
70–74	333	4.2	13.5	14.1	11.4	14.4	79.6
Race							
White	4896	1.6	6.9	7.5	16.4	8.5	22.7
Non-white	646	1.8	8.4	10.5	14.0	14.6	28.6
Sex							
Male	2508	2.2	10.0	9.8	16.1	8.8	28.3
Female	3034	1.2	4.6	6.2	16.1	9.6	19.2
Education							
⩽12 years	4044	1.9	7.6	8.3	16.6	9.0	24.2
⩾13 years	1498	0.9	5.2	6.8	14.8	10.1	21.0
Smoking status							
Current smoker	2323	2.5	11.8	10.3	20.2	10.0	30.2
Former smoker	1110	1.8	6.6	7.9	15.9	6.9	22.0
Never smoker	2109	0.9	2.8	5.9	10.5	9.4	17.9
Pack years							
⩾60	524	2.7	16.4	12.8	19.0	11.8	33.0
30–<60	961	2.9	12.8	11.0	24.1	9.6	29.5
<30	1948	1.4	5.5	7.6	16.8	8.8	23.7
Never smoker	2109	0.9	2.8	5.9	10.5	9.4	17.9
Years since regularly smoked							
0	2432	2.5	11.5	9.9	19.6	9.8	29.8
>0–<10	629	2.3	8.4	9.1	16.6	8.0	22.6
⩾10	372	0.8	4.9	6.1	16.1	5.7	20.1
Never smoker	2109	0.9	2.8	5.9	10.5	9.4	17.9
Body mass index (kg/m^2)							
<18.5	180	6.9	10.2	9.2	17.8	13.4	31.4
⩾18–24	2604	1.8	7.7	9.1	14.8	7.4	22.1
25–29	1885	1.1	6.7	8.0	16.1	9.3	23.1
⩾30	873	1.6	5.7	4.6	19.1	13.4	27.0
Total	5542	1.7	7.1	7.9	16.1	9.2	23.4

Participants included in the analysis were stratified by age, race, sex, education level, and smoking status at the baseline evaluation; the age adjusted* proportion within each subgroup with class of COPD, respiratory symptoms, or restrictive lung disease; and the age adjusted proportion who died during the follow up period.
*Age adjusted to the analytical population sample. Proportions by age are age specific.
**Severe COPD = forced expiratory volume in 1 second (FEV_1)/forced vital capacity (FVC) <0.70 and FEV_1 <50% predicted; moderate COPD=FEV_1/FVC <0.70 and FEV_1 ⩾50–<80% predicted; mild COPD=FEV_1/FVC <0.70 and FEV_1 ⩾80%; symptoms only=presence of respiratory symptoms in the absence of any lung function abnormality; restrictive lung disease=FEV_1/FVC ⩾0.70 and FVC <80% predicted.
From the First National Health and Nutrition Examination Survey 1971–5 and follow up to 1992.

smokers reported how long it had been since they smoked cigarettes fairly regularly.

Pulmonary function data

Spirometric data were obtained from participants in the cardiorespiratory module using an Ohio Medical Instruments 800 spirometer. The procedures used have been described previously.[13] Subjects were excluded from the analysis if they either did not perform spirometric tests or had results that were not reliable. Data were included from subjects who did not have "reproducible" measures (to be reproducible the FEV_1 and FVC from two reliable measurements had to be within 5% for most subjects).[18] Values used in the analysis included FVC, FEV_1, and the FEV_1/FVC ratio. Predicted values of FEV_1 and FVC were determined by performing linear regression (stratified by sex and by using age and height as predictors) on a subgroup of participants who were white never smokers who did not report respiratory symptoms or physician diagnosed lung disease. The results from these regression models (men: $FEV_1 = -4.3806 - age*0.031767 + height*0.13827$, $r^2 = 0.626$; $FVC = -7.49837 - age*0.03071 + height*0.19794$, $r^2 = 0.589$; women: $FEV_1 = -0.75683 - age*0.02475 + height*0.07131$, $r^2 = 0.539$; $FVC = -2.2086 - age*0.02394 + height*0.10381$, $r^2 = 0.451$) were applied to the data from all participants to obtain predicted values of FEV_1 and FVC. An adjustment factor of 0.88 was used to estimate predicted values for black participants.[19] Using a modification of the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria for COPD, participants were classified into the following mutually exclusive categories using FEV_1, FVC, the FEV_1/FVC ratio, and the presence of respiratory symptoms: severe COPD (FEV_1/FVC <0.70 and FEV_1 <50% predicted), moderate COPD (FEV_1/FVC <0.70 and FEV_1 ⩾50 to <80% predicted), mild COPD (FEV_1/FVC <0.70 and FEV_1 ⩾80%), symptoms only (presence of respiratory symptoms in the absence of any lung function abnormality), restrictive lung disease (FEV_1 ⩾0.70 and FVC <80% predicted), and no lung disease.

Death

Death certificate data were collected on NHANES I participants who died during the follow up period up to 1992 and were included in the NHANES I follow up database. We searched this database for all deaths and for deaths where COPD or related conditions (asthma, bronchiectasis; ICD-9 codes 490–496) were listed as either the underlying cause of death or as any cause of death.

Body mass index

Weight and height were measured at the examination. Body mass index was calculated by dividing each participant's

Table 2 Number of participants included in analysis stratified by smoking status and pulmonary function impairment, proportion who died during the follow up period, and proportion of deaths with either COPD listed as the underlying cause of death (UCD) or as any cause of death

	N	Deaths	Proportion of participants who died (%)	Proportion who died with COPD as UCD (%)	Proportion who died with any mention of COPD (%)
Current smokers					
Severe COPD*	48	37	77.1	29.7	51.4
Moderate COPD	247	116	47.0	5.2	16.4
Mild COPD	213	85	39.9	2.4	7.1
Respiratory symptoms only	494	90	18.2	2.2	8.9
Restrictive lung disease	224	83	37.1	4.8	9.6
No lung disease	1097	169	15.4	0.6	2.4
Total	2323	580	25.0	4.5	11.0
Former smokers					
Severe COPD	24	21	87.5	19	57.1
Moderate COPD	81	39	48.1	5.1	25.6
Mild COPD	96	30	31.3	0	0
Respiratory symptoms only	175	40	22.9	0	5.0
Restrictive lung disease	82	38	46.3	5.3	7.9
No lung disease	652	122	18.7	0.8	2.5
Total	1110	290	26.1	3.1	10.3
Never smokers					
Severe COPD	20	7	35.0	0	0
Moderate COPD	64	25	39.1	0	12.0
Mild COPD	130	42	32.3	0	0
Respiratory symptoms only	223	43	19.3	0	0
Restrictive lung disease	205	75	36.6	0	4.0
No lung disease	1467	239	16.3	0.4	2.1
Total	2109	431	20.4	0.2	2.6
All subjects					
Severe COPD	92	65	70.7	23.1	47.7
Moderate COPD	392	180	45.9	4.4	17.8
Mild COPD	439	157	35.8	1.3	3.8
Respiratory symptoms only	892	173	19.4	1.2	5.8
Restrictive lung disease	511	196	38.4	3.1	7.1
No lung disease	3216	530	16.5	0.6	2.3
Total	5542	1301	23.5	2.8	8.1

*Severe COPD = forced expiratory volume in 1 second (FEV_1)/forced vital capacity (FVC) <0.70 and FEV_1 <50% predicted; moderate COPD=FEV_1/FVC <0.70 and FEV_1 ⩾50–<80% predicted; mild COPD=FEV_1/FVC <0.70 and FEV_1 ⩾80%; symptoms only=presence of respiratory symptoms in the absence of any lung function abnormality; restrictive lung disease=FEV_1/FVC ⩾0.70 and FVC <80% predicted. From the First National Health and Nutrition Examination Survey 1971–5 and follow up to 1992.

weight in kilograms by the square of the height in meters. The following standard classifications were used: <18.5 kg/m^2 (underweight), ⩾18.5–24 kg/m^2 (normal), 25–29 kg/m^2 (overweight), ⩾30 kg/m^2 (obese).[20]

Analysis

Our primary outcome of interest was death, and the main predictor of interest in our analysis was baseline lung function. Analyses were performed using the statistical packages SAS (SAS Institute, Cary, NC, USA), SUDAAN (RTI, Research Triangle Park, NC, USA) and SPSS (SPSS Inc, Chicago, IL, USA). The results were similar in analyses performed both with and without the NHANES I sampling weights and complex design incorporated. Only the unweighted data are presented.

Cox proportional hazard regression models were developed using the SUDAAN procedure SURVIVAL to account for differential follow up in NHANES I participants. Time of follow up was used as the underlying time metric. For deaths, the exit date was the date of death reported on the death certificate and, for survivors, the exit date was the date the participant was last known to be alive. Plots of the log-log survival curves for each covariate were used to show that the proportional hazards assumptions were met. Lung function category, age, sex, race, smoking status, education level, body mass index, pulmonary function level, pack-years of cigarette smoking, and years since last smoked were included in the regression models and the models were evaluated for interactions.

RESULTS

A total of 14 407 adults aged 25–74 years participated in the nationally representative NHANES I survey. From this sample, 6913 (also nationally representative) participated in the cardiorespiratory survey and examination. We excluded 1371 subjects who either did not have pulmonary function testing done or had results which were not reliable, leaving 5542 in the final cohort for analysis. Subjects excluded because of missing or unreliable pulmonary function data were more likely to be older than 60 years (37.8% *v* 22.8%, $p<0.05$) and to be of non-white race (21.8% *v* 11.8%, $p<0.05$) than those included in the final cohort. During the follow up period, 44.7% of excluded subjects died compared with 23.5% of the cohort analysed.

The demographic characteristics of the cohort at baseline are shown in table 1. Overall, 1.7% of participants had evidence of severe COPD, 7.1% had evidence of moderate COPD, and 9.2% had evidence of restrictive lung disease at baseline. 860 of the 5542 subjects (15.5%) in the cohort analysed had non-reproducible spirometric measurements: 57.6% of those with severe COPD, 38.8% of those with restrictive lung disease, 30.6% of those with moderate COPD, 22.8% of those with mild COPD, 9.5% of those with no lung disease, and

Table 3 Proportional hazards model for death among all subjects in univariate and multivariate models

	Univariate models		Multivariate model*	
	Hazards ratio	95% CI	Hazards ratio	95% CI
Lung function				
Severe COPD**	6.6	5.1 to 8.6	2.7	2.1 to 3.5
Moderate COPD	3.5	3.0 to 4.2	1.6	1.4 to 2.0
Mild COPD	2.4	2.0 to 2.9	1.2	1.01 to 1.4
Respiratory symptoms only	1.3	1.1 to 1.5	1.2	0.97 to 1.4
Restrictive lung disease	2.6	2.3 to 3.2	1.7	1.4 to 2.0
No lung disease	1.0		1.0	
Age				
25–39	1.0		1.0	
40–49	3.0	2.3 to 4.1	2.7	2.0 to 3.6
50–59	7.2	5.6 to 9.3	6.0	5.0 to 7.9
60–69	17.9	13.9 to 22.9	16.3	12.6 to 21.2
70–74	37.8	29.1 to 49.1	37.1	28.1 to 49.0
Race				
White	1.0		1.0	
Non-white	1.4	1.2 to 1.6	1.2	0.97 to 1.4
Sex				
Male	1.6	1.5 to 1.8	1.6	1.4 to 1.9
Female	1.0		1.0	
Education				
⩽12 years	1.8	1.5 to 2.0	1.2	1.01 to 1.4
⩾13 years	1.0		1.0	
Smoking status				
Current smoker	1.3	1.2 to 1.5	1.4	1.2 to 1.7
Former smoker	1.4	1.2 to 1.6	1.1	0.9 to 1.4
Never smoker	1.0		1.0	
Pack years				
Never smoker	1.0			
<30	0.8	0.7 to 0.9	1.0	
30–<60	1.8	1.6 to 2.1	1.3	1.1 to 1.6
⩾60	2.7	2.3 to 3.2	1.3	1.1 to 1.5
Years since regularly smoked				
Never smoker	1.0			
0	1.7	1.4 to 2.1	1.3	1.0 to 1.7
0–<10	1.2	1.0 to 1.5	1.0	0.8 to 1.2
⩾10	1.3	1.2 to 1.5	1.0	
Body mass index (kg/m^2)				
<18.5	1.7	1.3 to 2.3	1.7	1.3 to 2.3
⩾18–24	1.0		1.0	
25–29	1.3	1.2 to 1.5	1.0	0.9 to 1.2
⩾30	1.7	1.4 to 1.9	1.4	1.2 to 1.7

*Models adjusted for lung function category, age, race, sex, education, smoking status, pack years of smoking, years since regularly smoked, and body mass index.
**Severe COPD = forced expiratory volume in 1 second (FEV_1)/forced vital capacity (FVC) <0.70 and FEV_1 <50% predicted; moderate COPD=FEV_1/FVC <0.70 and FEV_1 ⩾50–<80% predicted; mild COPD=FEV_1/FVC <0.70 and FEV_1 ⩾80%; symptoms only=presence of respiratory symptoms in the absence of any lung function abnormality; restrictive lung disease=FEV_1/FVC ⩾0.70 and FVC <80% predicted.
From the First National Health and Nutrition Examination Survey 1971–5 and follow up to 1992.

9.3% of those with respiratory symptoms only. The prevalence of all classes of COPD and restrictive lung disease increased with increasing age (table 1).

The median duration of follow up of the cohort was 17.9 years (interquartile range (IQR) 15.4–19.0). During the follow up period 1301 participants died. Subjects with severe COPD had the highest death rate (70.7%) during the follow up period, although this proportion varied with smoking status (table 2). Of those with severe COPD at baseline who died during follow up, 23.1% had COPD listed as the underlying cause of death and an additional 24.6% had COPD listed as a contributing cause of death (table 2, all subjects).

In the univariate proportional hazards model, all lung function impairment classifications—together with age, race, sex, education level, and smoking—were associated with an increased risk of death (table 3, fig 1). The number available for follow up at each time interval is shown in table 4. In the multivariate model severe COPD, moderate COPD, mild COPD, and restrictive lung disease were all associated with an increased risk of death (table 3). Adjustment for covariates diminished the effect of lung function impairment on mortality—for example, the hazards ratio for severe COPD

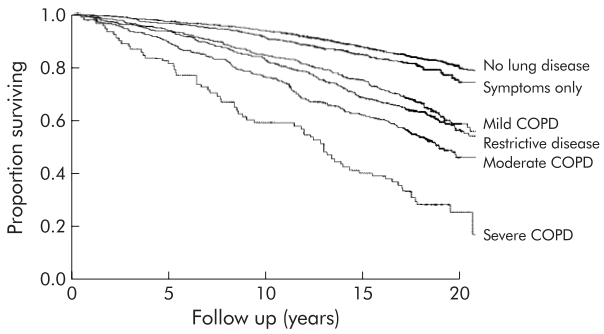

Figure 1 Kaplan-Meier curve for death among 5542 participants stratified by degree of lung function impairment (number available for follow up at each time interval is shown in table 4). From the National Health and Nutrition Examination Survey 1971–5 and follow up to 1992.

Table 4 Number available for follow up at each time interval

	0 years	5 years	10 years	15 years	20 years
Severe COPD	92	74	54	36	8
Moderate COPD	392	339	290	219	48
Mild COPD	439	398	359	313	62
Respiratory symptoms only	892	812	761	674	99
Restrictive lung disease	511	465	406	328	75
No lung disease	3216	3032	2911	2627	476
Total	5542	5120	4781	4197	768

Table 5 Proportional hazards model for death among subjects stratified by smoking status in univariate and multivariate models

	Univariate models		Multivariate model*	
	Hazards ratio	95% CI	Hazards ratio	95% CI
Current smokers				
Severe COPD**	8.0	5.6 to 11.5	3.1	2.2 to 4.4
Moderate COPD	3.9	3.1 to 4.9	1.7	1.4 to 2.2
Mild COPD	3.1	2.4 to 4.0	1.3	1.01 to 1.7
Respiratory symptoms only	1.3	0.99 to 1.7	1.3	0.97 to 1.7
Restrictive lung disease	2.8	2.1 to 3.6	1.7	1.3 to 2.1
No lung disease	1.0		1.0	
Former smokers				
Severe COPD	9.0	5.8 to 14.1	3.5	2.2 to 5.6
Moderate COPD	3.1	2.1 to 4.5	1.9	1.3 to 2.7
Mild COPD	1.7	1.1 to 2.6	0.98	0.7 to 1.5
Respiratory symptoms only	1.2	0.9 to 1.8	1.1	0.7 to 1.6
Restrictive lung disease	2.7	1.9 to 3.9	2.0	1.4 to 2.9
No lung disease	1.0		1.0	
Never smokers				
Severe COPD	2.4	1.1 to 5.3	1.4	0.7 to 3.1
Moderate COPD	2.9	1.9 to 4.5	1.3	0.8 to 2.1
Mild COPD	2.1	1.5 to 3.0	1.3	0.95 to 1.8
Respiratory symptoms only	1.3	0.9 to 1.8	1.1	0.8 to 1.5
Restrictive lung disease	2.6	2.0 to 3.4	1.6	1.2 to 2.1
No lung disease	1.0		1.0	

*Models adjusted for lung function category, age, race, sex, education, smoking status, pack years of smoking, years since regularly smoked, and body mass index.
**Severe COPD = forced expiratory volume in 1 second (FEV_1)/forced vital capacity (FVC) <0.70 and FEV_1 <50% predicted; moderate COPD=FEV_1/FVC <0.70 and FEV_1 ⩾50–<80% predicted; mild COPD=FEV_1/FVC <0.70 and FEV_1 ⩾80%; symptoms only=presence of respiratory symptoms in the absence of any lung function abnormality; restrictive lung disease=FEV_1/FVC ⩾0.70 and FVC <80% predicted.
From the First National Health and Nutrition Examination Survey 1971–5 and follow up to 1992.

decreased from 6.6 (95% CI 5.1 to 8.6) in the univariate model to 2.7 (95% CI 2.1 to 3.5) in the multivariate model.

Although we did not detect a significant interaction between lung function category and smoking status (p=0.56), we stratified the cohort by smoking status because of the biological plausibility that the development, progression, and outcomes of lung disease differ between smokers and never smokers.[21] In the multivariate proportional hazard models stratified by smoking status, moderate and severe COPD were associated with an increased mortality risk in current and former smokers, but not in never smokers (table 5). Conversely, restrictive lung disease was associated with an increased risk of mortality to a similar extent in all three smoking categories (table 5).

DISCUSSION

In this analysis of a nationally representative cohort of the US population followed for up to 22 years, the presence of moderate or severe COPD or restrictive lung disease at baseline was associated with an increased risk of death. Fewer than half of those who had moderate or severe COPD at baseline and died had a diagnosis of COPD listed anywhere on their death certificate.

One difference between this and previous studies of the relation between lung function and mortality is the use of GOLD criteria to define baseline lung function. Previous studies have used quintiles or tertiles of FEV_1 in the analysis,[11 22] continuous FEV_1[6 9] or an FEV_1 of >50% as the referent group.[7] Most other studies which used only FEV_1 to categorise subjects may include both subjects with restrictive disease and those with obstructive disease.[11 23] Prior analyses of the NHANES I data, which included deaths up to 1987, only used FEV_1 to classify lung disease,[6 24] although one did incorporate transfer factor (which was available on a subset of the database) into the analysis.[6]

An interesting finding in our analysis was that, in never smokers, moderate or severe COPD did not have a significantly increased mortality risk. This is consistent with previous findings that obstructive lung function impairment related primarily to asthma is less lethal than that related to emphysema or chronic bronchitis.[21] Conversely, never smokers with restrictive lung disease had an increased mortality hazard similar to that seen in current and former smokers. Former smokers with either severe or moderate COPD had a mortality risk similar to that seen in current smokers. This could be related to the observation that some former smokers may continue to lose lung function at an accelerated rate.[25]

The precise mechanisms by which lung disease causes early non-respiratory mortality are unknown, but may be related to chronic muscle wasting, autonomic dysfunction, systemic inflammation, oxidative stress, or other factors.[26–31] Another possibility is that mechanisms leading to reduced pulmonary function may cause death from other causes, but there may be no causal relationship.[9–11]

As was shown in a smaller study in Tucson, Arizona,[32] our analyses suggest that COPD is under-reported on death certificates. This could be due to one of several factors: (1) the deceased may never have been diagnosed with COPD, (2) the deceased may have been diagnosed with COPD but the person certifying the death did not feel this was a factor in the death, or (3) the death certificate may have been completed by a person unfamiliar with the medical history of the deceased person.[4 33]

This analysis has certain limitations. Lung function was only obtained at the baseline examination so we could not determine the effect of lung function decline on mortality.[22 23] Smoking status, which is an important predictor of mortality, was not independently validated with biomarkers. Diagnosed lung disease and respiratory symptoms were all self-reported and not independently validated. Data on total lung capacity, which are needed for the strict definition of restrictive lung disease,[34] were not available so it is possible that some subjects classified as restrictive had other pathology or normal lung volumes.[35] Finally, 15.5% of subjects had non-reproducible spirometric parameters, with this proportion being much higher among subjects with lung disease. The net effect of these final two biases would classify people with normal lung function as having restrictive or obstructive lung disease and would probably underestimate the effect of restrictive or obstructive lung disease on mortality.

In conclusion, both obstructive and restrictive pulmonary impairment are associated with an increased risk of mortality during follow up. This finding may be clinically important, particularly with regard to restrictive lung disease which can have several different aetiologies and requires clinical evaluation. Increased use of spirometric testing in the periodic adult health screen, which is being promoted by the National Lung Health Education Program,[36] would probably increase the early detection of both restrictive and obstructive lung diseases.

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