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Prevalence of spirometry-defined airflow obstruction in never-smoking working US coal miners by pneumoconiosis status

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Abstract

Introduction—This study estimated the prevalence of spirometry-defined airflow obstruction and coal workers' pneumoconiosis (CWP) among never-smoking coal miners participating in the National Institute for occupational Safety and health (NIOSH) Coal Workers' health Surveillance program (CWHSP).

Methods—Data were from working miners screened by a CWHSP mobile unit who had valid spirometry and chest radiography results. Spirometry-defined airflow obstruction was determined when the ratio of forced expiratory volume in the first second to forced vital capacity is less than the lower limit of normal. Chest radiographs were classified according to the International Labour office system to identify pneumoconiosis, including the most severe form of pneumoconiosis, progressive massive fibrosis (PMF).

Results—Prevalence of airflow obstruction among never-smoking coal miners in this sample was 7.7% overall, 16.4% among miners with CWP and 32.3% among miners with PMF. Airflow obstruction was significantly associated with CWP and PMF.

Conclusions—There was a higher prevalence of airflow obstruction among never-smoking coal miners with pneumoconiosis compared with those without pneumoconiosis. these findings support prior research on airflow obstruction and smoking and show pneumoconiosis might present with an obstructive pattern regardless of smoking status.

INTRODUCTION

Coal mine dust exposure causes airway inflammation and is associated with lung function impairment.¹² Although cigarette smoking is a major risk factor for obstructive lung disease,

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obstructive disease also occurs in never-smoking coal miners. Furthermore, coal workers' pneumoconiosis (CWP) is associated with emphysema and airflow obstruction.³ For example, 15% of non-smoking bituminous coal miners in Turkey with radiographic evidence of CWP had emphysema and 51% had airflow obstruction, defined using spirometry measured as the ratio of forced expiratory volume in the first second to forced vital capacity (FEV_1/FVC) <0.70 .³ To examine the burden of obstructive disease and CWP in never-smoking coal miners, we determined the prevalence of spirometry-defined airflow obstruction and CWP among a subset of working miners participating in the National Institute for Occupational Safety and Health (NIOSH) Coal Workers' Health Surveillance Program (CWHSP).

METHODS

Implemented in 2005 to complement the existing network of clinics approved by NIOSH to provide CWHSP services, the Enhanced CWHSP (ECWHSP) offers respiratory health screening consisting of spirometry testing, a chest radiograph, and a questionnaire (obtaining demographic information, work history, respiratory health symptoms, previous diagnoses and smoking history) to coal miners using a mobile examination unit, which travels to coal mining regions throughout the USA.^{4,5} All coal miners (underground, surface and contractor miners) are invited to participate in the surveillance programme.⁵ The entire CWHSP has a non-research designation and is exempt from NIOSH Human Subjects Review Board approval (11-DRDS-NR03), and participants provide informed consent.

Spirometry testing was administered by NIOSH-trained technicians following the American Thoracic Society and European Respiratory Society (ATS/ERS) guidelines and performed using a dry-rolling seal volume spirometer.⁶ Airflow obstruction was defined per ATS/ERS criteria as $FEV_1/FVC < \text{lower limit of normal (LLN)}$, calculated using predication equations from the Third National Health and Nutrition Examination Survey (NHANES III).⁷ Those with airflow obstruction were further evaluated to identify moderate/severe airflow obstruction when $FEV_1/FVC < \text{LLN}$ and $FEV_1 < 70\%$ of the predicted value.⁷ At the time of spirometry testing, miners reported their age, sex, race and smoking status (ever/never smoker).

Chest radiographs were classified by at least two NIOSH-certified physician B Readers according to the International Labour Office system.⁸ CWP was defined as the presence of small opacity profusion subcategory 1/0 or greater and further classified using major category scales (1, 2, 3).⁸ Among those with CWP, progressive massive fibrosis (PMF), the most severe form of the disease, was defined as the presence of large opacities >1 cm (category A, B or C).⁸

As part of the respiratory health screening, miners provided mining tenure and mining type details. 'Surface only' miners reported tenure solely in surface mines and 'underground only' miners reported tenure solely in underground mines. Miners reporting tenure in both surface and underground mines were 'both surface & underground' miners. We determined surface tenure from the reported years of surface mining and underground tenure from years

of underground mining. Total mining tenure was the sum of tenure in surface and underground mines.

Statistical analyses were performed using SAS V.9.4 (SAS Institute Inc. Cary, North Carolina, USA). Frequencies of demographic and mining characteristics, airflow obstruction and pneumoconiosis were calculated. Chi-square or Fisher exact tests were used to compare frequencies and were considered significant at $p < 0.05$. Multivariable logistic regression calculated the odds of obstruction by pneumoconiosis status adjusting for age (which correlated with total tenure).

RESULTS

From September 2005 through August 2016, 12 592 spirometry tests and 17 939 radiographs were conducted as part of the ECWHSP. We included 12 080 spirometry tests (95.9%) with at least two acceptable manoeuvres and variability within 200 mL between the values of the best two manoeuvres.⁶ From encounters with both a spirometry test and corresponding classified chest radiograph ($n=11\,791$), we selected a miner's most recent encounter and excluded 621 former miners no longer working at the time of screening and 50 with missing smoking information resulting in 5316 never and 5034 ever-smoking miners.

Among the 5316 never-smoking coal miners, 2.2% had CWP ($n=116$) and among those with CWP, 26.7% ($n=31$) had PMF. The mean age for never-smoking miners was 45.9 years (range: 15–76 years), and most were white (91.7%), men (97.0%) and employed underground only (65.7%) (table 1). The mean surface mining tenure was 13.1 years, mean underground mining tenure was 18.9 years and mean total mining tenure was 19.8 years.

The overall prevalence of airflow obstruction among never-smoking miners was 7.7%. The prevalence of airflow obstruction among those with CWP was 10.6% among miners with simple CWP and 32.3% among miners with PMF. The overall prevalence of moderate/severe airflow obstruction among never-smoking miners was 1.1%; 1.2% among miners with simple CWP and 9.7% among miners with PMF. Airflow obstruction was significantly associated with CWP ($p=0.0004$), PMF ($p<0.0001$) and age group ($p=0.0406$), and the regression model identified a higher likelihood of obstruction among miners with PMF compared with those without pneumoconiosis (OR=6.34, 95% CI: 2.95 to 13.63). Moderate/severe airflow obstruction was also significantly associated with CWP ($p=0.0351$) and PMF ($p=0.0042$). The prevalence of airflow obstruction and moderate/severe airflow obstruction was similar among never-smoking miners regardless of mining type (surface only 6.6%, 1.2%; underground only 8.2%, 1.1%; surface & underground mining 6.9%, 0.7%).

DISCUSSION

Never-smoking working miners with CWP, identified by a chest radiograph as part of a voluntary surveillance programme, had a significantly higher prevalence of ATS/ERS airflow obstruction (16.4%) and moderate/severe airflow obstruction (3.5%) compared with those without CWP (7.5% and 1.0%, respectively), and airflow obstruction was more common in miners with PMF compared with those with simple CWP. A study of non-

smoking Chinese underground miners with pneumoconiosis, identified in a clinical setting, reported the prevalence of Global Initiative for Chronic Obstructive Lung Disease (GOLD)-defined chronic obstructive pulmonary disease among these miners was 18.7%.⁹ In our study, airflow obstruction prevalence was highest in never-smoking miners with PMF (32.3%), indicating severe cases of pneumoconiosis can present with an obstructive pattern regardless of smoking status. Among working miners with a history of smoking (n=5034), the prevalence of airflow obstruction was 16.7% among those with no CWP and ranged from 29.4% among those with simple CWP (27.9% for category 1 and 34.0% for categories 2–3) to 34.4% among those with PMF (data not shown).

Among ever-employed, never-smoking US adults aged 18–79 years, the age-standardised prevalence of spirometry-defined airflow obstruction (7.2%) and moderate/severe airflow obstruction (0.8%) was similar to the crude (7.7%) and age-standardised (8.2%) prevalence of airflow obstruction and crude (1.1%) and age-standardised (1.0%) prevalence of moderate/severe airflow obstruction (1.1%) in our study of never-smoking miners.¹⁰ The age-standardised prevalence of airflow obstruction among US adults reporting exposure to mineral dust ('dust from rock, sand, concrete, coal, asbestos, silica or soil') was 7.3%.¹¹ Similar prevalence of airflow obstruction in working coal miners and US adults may result from the healthy worker effect as ever-employed adults tend to be fitter and have better lung function compared with non-workers. Healthy workers, including older miners with longer tenure, may remain in the coal mining industry, whereas less healthy workers leave as suggested by the slight, but not statistically significant, decrease in airflow obstruction prevalence with a longer surface, underground and total mining tenure (table 1).

Participation in the CWHSP is voluntary and about 37% of actively employed workers at underground mines received a chest radiograph as part of the CWHSP from 2005 to 2014 (https://wwwn.cdc.gov/eworld/Grouping/Coal_Workers_Pneumoconiosis/93). Prevalence estimates in this study may not be representative of all never-smoking working US coal miners. The small sample size for some pneumoconiosis categories and mining variables limits statistical power for analyses examining differences in the prevalence of obstruction by mining tenure and simple CWP category.

Among miners with a radiograph but no corresponding spirometry test, approximately 40% were missing spirometry because their encounter occurred during outreach to surface miners, which excluded spirometry (2010–2012). Other miners with an encounter but no spirometry either refused to perform spirometry, could not perform spirometry due to contraindications (eg, high blood pressure, recent surgery, history of heart problems and current cold) or had poor spirometry quality; therefore, results likely exclude miners with substantial respiratory morbidity. Furthermore, we relied on self-reported smoking status and lacked a clinical obstructive lung disease diagnosis. A clinical diagnosis would strengthen this study by confirming cases of airflow obstruction to reduce the likelihood of case misdiagnosis. Additional details on airflow obstruction type (eg, chronic bronchitis and emphysema) would help explain mechanisms of obstructive impairments in never-smoking coal miners with and without CWP. Of interest in non-smoking miners with obstruction is the presence of fibrotic scarring from focal emphysema as it signifies CWP and is not attributed to smoking.³

Monitoring and understanding lung function in coal miners is especially important as lung function decline is predictive of morbidity and mortality.⁷ Decreasing lung function across increasing subcategories of simple CWP was identified in miners with a 2005–2013 ECWHSP encounter after controlling for smoking status, body mass index and underground mining tenure.¹² By limiting our analysis to never smokers, we excluded the effects of smoking and found airflow obstruction occurs in never-smoking coal miners with and without pneumoconiosis, with the highest prevalence among those with CWP and PMF.

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Key messages

What is already known about this subject?

- Cigarette smoking is associated with obstructive lung disease. However, obstruction may also result from occupational exposures, such as coal mine dust exposure or fibrotic scarring from pneumoconiosis. After excluding the effect of smoking on coal miners, obstructive lung disease occurs in coal miners with and without pneumoconiosis.

What are the new findings?

- The prevalence of airflow obstruction among never-smoking coal miners participating in the Coal Workers' Health Surveillance Program (CWHSP) was 7.7% overall and the prevalence increased with increasing severity of pneumoconiosis.

How might this impact on policy or clinical practice in the foreseeable future?

- It is important to identify and address airflow obstruction in never-smoking coal miners with and without pneumoconiosis in order to adequately manage and prevent respiratory disease associated with coal mine dust exposure.

Table 1

Unadjusted prevalence of airflow obstruction and moderate/severe airflow obstruction among never-smoking coal miners

Characteristics	No. sample (n=5316)	Prevalence of airflow obstruction (n=410)	Prevalence of moderate/severe airflow obstruction (n=57)
		percent	percent
Total		7.7	1.1
No coal workers' pneumoconiosis (category 0)	5200	7.5*	1.0*
All coal workers' pneumoconiosis	116	16.4	3.5
Simple coal workers' pneumoconiosis	85	10.6	1.2
Category 1	67	10.5	1.5
Categories 2–3	18	11.1	0.0
Progressive massive fibrosis	31	32.3*	9.7*
Age group (years)			
<40	1645	8.4*	0.6
40–49	1247	7.5	1.0
50–59	1968	6.7	1.4
60	456	10.3	1.5
Sex			
Male	5159	7.8	1.1
Female	157	5.1	1.3
Race			
White	4874	7.8	1.1
Other	442	7.0	0.7
Surface only miners	982	6.6	1.2
Underground only miners	3437	8.2	1.1
Both surface & underground miners	810	6.9	0.7
Surface mining tenure (years)	Mean=13.1		
1–<10	965	7.2	0.9
10–25	428	5.6	0.9
25	399	7.0	1.3
Underground mining tenure (years)	Mean=18.9		
1–<10	1351	8.5	0.6
10–25	1152	7.2	1.1
25	1744	8.0	1.3
Total mining tenure (years)	Mean=19.8		
1–<10	1606	8.3	0.8
10–25	1292	7.0	1.2
25	2331	7.7	1.2

Miner type and mining tenure data were missing for 87 miners.

* Indicates significant p value (<0.05) based on χ^2 or Fisher exact test.