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Respiratory morbidity among U.S. coal miners in states outside of central Appalachia

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Abstract

Background—Recent NIOSH publications have focused on the respiratory health of coal miners in central Appalachia, yet 57% of U.S. coal miners work in other regions. We characterized respiratory morbidity in coal miners from these regions.

Methods—Active coal miners working outside of central Appalachia who received chest radiographs and/or spirometry during 2005–2015 were included. Chest radiographs were classified according to International Labour Office standards and spirometry was interpreted using the American Thoracic Society guidelines. Prevalence of coal workers' pneumoconiosis (CWP) and abnormal spirometry were compared by region.

Results—A total of 103 (2.1%) miners had CWP. The eastern region had the highest prevalence (3.4%), followed by the western (1.7%), and interior (0.8%) regions. A total of 524 (9.3%) miners had abnormal spirometry.

Conclusions—CWP occurs in all U.S. coal mining regions. Prevalence of CWP was higher in the eastern region, but lower than levels reported in central Appalachia.

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AUTHORS' CONTRIBUTIONS

LER analyzed and interpreted the data and led writing the article. ASL assisted with interpreting data and writing the article. DJB and CNH assisted with statistical software coding, interpreting data, writing the article, and conceptualization and design.

ETHICS APPROVAL AND INFORMED CONSENT

Enhanced Coal Workers' Health Surveillance Program is a surveillance program with non-research designation and is exempt from NIOSH Human Subjects Review Board approval (11-DRDS-NR03).

DISCLOSURE (AUTHORS)

The authors report no conflicts of interest.

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Steven Markowitz declares that he has no conflict of interest in the review and publication decision regarding this article.

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the NIOSH. The Centers for Disease Control and Prevention NIOSH supported the salaries of the authors. This work was performed by U.S. Federal Government employees as part of their work; no non-governmental funding supported this work.

Keywords

coal mining; coal workers' pneumoconiosis; lung function impairment; reduced lung function; surveillance

1 | INTRODUCTION

Recent reports on coal miners' health in the United States have primarily focused on underground miners in Kentucky, Virginia, and West Virginia, commonly referred to as central Appalachia.[1–3] In 2005, the National Institute for Occupational Safety and Health (NIOSH) implemented the Enhanced Coal Workers' Health Surveillance Program (ECWHSP).[4] The ECWHSP's mobile examination unit has targeted regions where coal workers' pneumoconiosis (CWP) is more common; areas where NIOSH's routine surveillance program, the Coal Workers Health Surveillance Program (CWHSP), has had low participation; and surface miners who were not covered under routine surveillance.[4,5] The ECWHSP mobile examination unit has traveled across the U.S. collecting respiratory health information, including chest radiographs and spirometry, from underground and surface coal miners.

Coal is mined in approximately half of all U.S. states and miners working outside central Appalachia account for 57.1% of the country's 65 000 coal miners.[6] To characterize the respiratory health of this understudied population, we analyzed ECWHSP data collected from active underground and surface miners working in the eastern (excluding central Appalachia), interior, and western coal mining regions (defined below).

2 | METHODS

2.1 | Miners

We included active coal miners working in states outside central Appalachia, who participated in the ECWHSP during 2005–2015. NIOSH staff collected demographic information and occupational histories. Among miners receiving spirometry, smoking status (categorized as ever smoker or never smoker), height, and weight were obtained. Body mass index (BMI, kg/m^2) was calculated using the miner's measured height and weight. Coal mining tenure was the sum of reported years of underground and surface mining. We retained data from each miner's most recent ECWHSP encounter. ECWHSP is part of a national surveillance program with a non-research designation, and is exempt from NIOSH Human Subjects Review Board approval (11-DRDS-NR03).

2.2 | Medical testing

NIOSH technicians administered chest radiographs in the ECWHSP mobile unit. Radiographs were classified according to the International Labour Office (ILO) *International Classification of Radiographs of Pneumoconiosis*[7] system by at least two certified NIOSH physician B Readers.[8] Our surveillance definition of CWP was a profusion of small opacities subcategory 1/0 or greater, while progressive massive fibrosis (PMF), the most

severe form of CWP, was defined as the presence of large opacities (>1 cm; category A, B, or C).[7]

Spirometry was administered by trained NIOSH technicians using a dry-rolling seal volume spirometer, and interpreted using the 2005 American Thoracic Society and European Respiratory Society guidelines.[9,10] Tests with at least three acceptable maneuvers showing maximal effort and repeatable FEV_1 and FVC were included. Miners' FEV_1 and FVC results were compared to predicted lower limits of normal (LLN) based on their respective age, sex, and race, using reference equations derived from the Third National Health and Nutrition Examination Survey (NHANES).[11] Spirometry results were classified into four patterns: normal, obstructive, restrictive, and mixed as previously described.[3]

2.3 | Coal mining regions

The state in which a participating miner was employed at the time of their ECWHSP encounter was recorded, and these states were divided into three coal mining regions. The eastern region included Alabama, Maryland, Ohio, Pennsylvania, and Tennessee. The interior region included Illinois, Indiana, Louisiana, Oklahoma, and Texas. The western region included Arizona, Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming.

2.4 | Analysis

Because CWP is a disease of long latency, we restricted analysis of radiographs to miners with at least 10 years of tenure. Demographics and other participant characteristics were evaluated using the chi-square test for independence for categorical variables and analysis of variance (ANOVA) for continuous variables. The prevalence of abnormal spirometry and pneumoconiosis were compared by region using the chi-square test for independence or Fisher's Exact test. Data were analyzed using SAS 9.4 (Cary, NC).

3 | RESULTS

3.1 | Miners

The ECWHSP evaluated 7949 active coal miners working in the eastern, interior, and western regions during 2005–2015. Participating contract miners ($n = 142$; 1.8%) were excluded due to unknown mining state and mine type (underground or surface). Miners with fewer than 10 years of tenure were excluded from analysis of radiographic results, leaving 4985 (64%) eligible for this portion of analysis. Miners of all tenures who performed spirometry were considered for the lung function portion of analysis. Among miners who performed spirometry ($n = 5772$), 167 were excluded due to poor quality results, leaving 5605 (97%) miners for spirometry analysis.

3.2 | Radiograph results

A total of 103 (2.1%) miners had radiographic evidence of CWP (Table 1). The prevalence of CWP differed across regions ($P < 0.0001$). The eastern region had the highest prevalence of CWP (3.4%) and PMF (0.5%), compared to 1.7% and 0.1%, respectively, in the western region. The interior region had the lowest prevalence of CWP (0.8%), and zero cases of

PMF were identified. Miners working in Pennsylvania accounted for 33.0% ($n = 34$), and 80.0% ($n = 8$) of the total CWP and PMF cases, respectively. Among underground and surface miners, the prevalence of CWP differed across regions. The eastern region had the highest prevalence of CWP for both underground (3.1%) and surface (3.9%) miners. Of the 2822 miners excluded for having fewer than 10 years of tenure, 11 had CWP (median tenure = 7 years; range 0–8 years), and zero had PMF.

3.3 | Spirometry results

Of the 5605 miners included in spirometry analysis, 524 (9.3%) had abnormal results (Table 2). A total of 213 (10.3%) and 160 (10.2%) of miners in the eastern and interior regions, respectively, had abnormal spirometry, compared to 151 (7.7%) of miners in the western region. An obstructive pattern of impairment was more common among miners from the interior region (4.2%), while the eastern region had the highest prevalence of restrictive and mixed patterns (6.3% and 1.0%, respectively). The prevalence of a restrictive pattern of impairment differed across regions ($P < 0.0001$). Among the 70 miners with CWP and at least 10 years of tenure who performed spirometry, 14 (20.0%) had abnormal spirometry, compared to 10.2% of miners without CWP and at least 10 years of mining ($P = 0.0080$).

4 | DISCUSSION

We documented cases of CWP in every U.S. coal mining region and in both underground and surface miners. Recent reports have focused on increases in coal mine dust-related respiratory disease in central Appalachia,[2,3,12] but these findings point to an ongoing need for prevention and surveillance wherever coal miners work. Previous studies of respiratory morbidity in all U.S. coal mining regions have generally found lower rates of CWP and respiratory impairment among miners in regions outside of central Appalachia.[5,13,14] However, these reports did not include surface miners or surveys of interior and western coal field miners.

The ECWHSP is a unique surveillance system that collects high quality radiographs, spirometry, and health information from miners working in all coal mining regions throughout the United States. During the past several years the ECWHSP has focused on offering respiratory health screening to miners working in regions that had low participation in the routine surveillance program. This is the first report on respiratory morbidity among these miners by region, using 10 years of ECWHSP data.

Among the regions included in this analysis, we found miners in the eastern coal fields to have a higher prevalence of CWP, PMF, and miners with a restrictive pattern of lung function impairment. Although the prevalence of CWP and PMF in the eastern region (3.4% and 0.5%, respectively) is lower than that observed in central Appalachia, it is consistent with previous studies showing an increased CWP burden among coal miners in Appalachian mining states.[5] Miners in the eastern region were older, had longer tenure, and were more likely to have worked in underground coal mines, which partly may explain the higher prevalence of CWP and PMF in this region.

All miners with high quality spirometry results, regardless of reported tenure, were included for lung function analyses. Previous studies have found an association between inhaled coal mine dust and chronic airway disease.[15,16] Miners whose lung function is affected by coal mine dust exposure tend to experience larger declines in FVC and FEV_1 during the early years of their career, after which losses can continue, but at a lower rate.[17] This study found that miners with at least 10 years of tenure and evidence of CWP had twice the prevalence of lung function impairment, compared to miners of the same tenure and normal radiographs. This finding supports recent studies of underground coal miners which found an association between increasing profusion of opacities and decreased lung function.[5,18]

Our results are in line with previous studies that have demonstrated higher prevalences of CWP and PMF in the eastern coal fields. Higher disease prevalence has been associated with coal rank, mine employment size, mine seam height, and mining practices.[3,13,14,19–21] These risk factors differ across mining regions, and likely play a role in the differences in CWP prevalence and lung function impairment we observed in this report. However, it is important to note that our study found that both underground and surface miners working in each of the U.S. coal-mining regions have developed CWP and lung function impairment. Because CWP is a disease of long latency, we restricted analysis of radiographs to miners with at least 10 years of tenure. However, among those with fewer than 10 years of tenure, we identified 11 cases of CWP; this finding merits further attention.

This study is subject to limitations. The ECWHSP is a voluntary, targeted surveillance program. The participating miners were not a random sample of all U.S. coal miners, but rather, worked in areas with low participation in the CWHSP. Reasons for participating in the ECWHSP are not completely understood, but a previous study reviewing the potential biases found that ECWHSP data did not have a higher prevalence of CWP compared to the routine surveillance system.[22] By using ECWHSP data, we were able to characterize respiratory morbidity among these understudied coal mining regions. Some of the ECWHSP data including coal mining tenure and smoking status were self-reported, which could have led to misclassification for these measures. We also assigned miners to mining regions using the location of employment at the most recent ECWHSP encounter, and it is possible that some miners worked a majority of their career in one region and moved to a different region in their most recent ECWHSP visit.

Although the entire burden of CWP, and a portion of the lung function impairment, is preventable through effective control of respirable coal mine dust,[15] new cases of CWP continue to occur throughout the United States. This study highlights the importance of achieving and maintaining safe working environments in all coal mines. In 2014, the U.S. Mine Safety and Health Administration issued a new Federal rule, lowering the respirable dust standard, and mandating the expansion of the CWHSP to enhance health protections for our nations' coal miners. In addition to chest radiographs, the CWHSP now includes spirometry and respiratory health questionnaires for all coal miners, including contractors and surface miners. With the expansion of routine surveillance, future studies can explore regional differences of respiratory morbidity among coal miners. NIOSH will continue monitoring the health of all U.S. coal miners, and remains committed to reducing the risk of this entirely preventable respiratory disease among coal miners.

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TABLE 1

Characteristics of active coal miners with at least 10 years of tenure who received an ECWHSP radiograph by region, 2005–2015 (N = 4985)

	Eastern	Interior	Western	
Total, n	**1793**	**1259**	**1933**	**P-value***
Characteristics				
Sex, *n* male (%)	1764 (98.4)	1228 (97.5)	1837 (95.0)	<0.0001
Race, *n* white (%)	1659 (92.6)	1208 (96.2)	1465 (75.8)	<0.0001
Age, mean (SD)	53.5 (7.4)	51.2 (8.5)	51.8 (8.4)	<0.0001
Tenure, mean (SD)	28.9 (8.4)	24.8 (9.1)	25.2 (9.1)	<0.0001
Mine Type, *n* UG (%)	1179 (65.8)	588 (46.7)	1025 (53.0)	<0.0001
ILO Classification				
CWP[a], *n* (%)	61 (3.4)	10 (0.8)	32 (1.7)	<0.0001
PMF[b], *n* (%)	8 (0.5)	0	2 (0.1)	0.0120
Underground, *n*	1179	588	1025	
CWP, *n* (%)	37 (3.1)	3 (0.5)	22 (2.2)	0.0019
PMF, *n* (%)	2 (0.2)	0	1 (0.1)	0.1964
Surface, *n*	614	671	908	
CWP, *n* (%)	24 (3.9)	7 (1.0)	10 (1.1)	<0.0001
PMF, *n* (%)	6 (1.0)	0	1 (0.1)	0.0014

[a] Coal worker's pneumoconiosis.

[b] Progressive massive fibrosis.

* Fisher's Exact test used when cell size <5, all others chi-square or ANOVA was used.

TABLE 2

Characteristics of active coal miners, regardless of tenure, who received ECWHSP spirometry by region, 2005–2015 (N = 5605)

	Eastern	Interior	Western	
Total, n	**2065**	**1570**	**1970**	**P-value***
Characteristics				
Sex, *n* male (%)	2023 (98.0)	1510 (96.2)	1883 (95.6)	<0.0001
Race, *n* white (%)	1860 (90.2)	1504 (95.9)	1698 (86.2)	<0.0001
Age, mean (SD)	47.4 (11.5)	45.1 (11.5)	44.6 (12.1)	<0.0001
Tenure, mean (SD)	20.8 (13.3)	16.8 (12.1)	16.8 (12.5)	<0.0001
Mine Type, *n* UG (%)	1584 (76.7)	954 (60.8)	1466 (74.4)	<0.0001
Ever smoker, *n* (%)[a]	948 (45.9)	837 (53.1)	864 (43.9)	0.0001
BMI, mean (SD)[a]	30.8 (5.2)	30.5 (5.2)	29.5 (5.1)	<0.0001
Spirometry				
Abnormal, *n* (%)	213 (10.3)	160 (10.2)	151 (7.7)	0.0062
Obstructive, *n* (%)	61 (3.0)	66 (4.2)	74 (3.8)	0.1174
Restrictive, *n* (%)	131 (6.3)	83 (5.3)	65 (3.3)	<0.0001
Mixed, *n* (%)	21 (1.0)	11 (0.7)	12 (0.6)	0.3085
% pred FEV_1, mean (SD)	97.2 (14.1)	97.5 (13.5)	100.0 (14.5)	<0.00001
% pred FVC, mean (SD)	99.0 (12.8)	100.1 (12.1)	103.4 (13.0)	<0.00001
FEV_1/FVC, mean (SD)	77.1 (7.1)	76.9 (7.3)	76.5 (7.5)	0.0231

UG, underground; BMI, body mass index (kg/m^3).

[a]Data for smoking and BMI are collected during the spirometry exam.

*Fisher's Exact test used when cell size <5, all others chi square or ANOVA was used.