

Profusion of Opacities in Simple Coal Worker's Pneumoconiosis Is Associated With Reduced Lung Function

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BACKGROUND: A large body of evidence demonstrates dose-response relationships of cumulative coal mine dust exposure with lung function impairment and with small-opacity profusion. However, medical literature generally holds that simple coal worker's pneumoconiosis (CWP) is not associated with lung function impairment. This study examines the relationship between small-opacity profusion and lung function in US underground coal miners with simple CWP.

METHODS: Miners were examined during 2005 to 2013 as part of the Enhanced Coal Workers' Health Surveillance Program. Work histories were obtained, and chest radiographs and spirometry were administered. Lung parenchymal abnormalities consistent with CWP were classified according to International Labor Organization guidelines, and reference values for FEV₁ and FVC were calculated using reference equations derived from the third National Health and Nutrition Examination Survey. Differences in lung function were evaluated by opacity profusion, and regression models were fit to characterize associations between profusion and lung function.

RESULTS: A total of 8,230 miners were eligible for analysis; 269 had category 1 or 2 simple CWP. Decrements in FEV₁ % predicted were nearly consistent across profusion subcategories. Clear decrements in FVC % predicted and FEV₁/FVC were also observed, although these were less consistent. Controlling for smoking status, BMI, and mining tenure, each 1-unit subcategory increase in profusion was associated with decreases of 1.5% (95% CI, 1.0%-1.9%), 1.0% (95% CI, 0.6%-1.3%), and 0.6% (95% CI, 0.4%-0.8%) in FEV₁ % predicted, FVC % predicted, and FEV₁/FVC, respectively.

CONCLUSIONS: We observed progressively lower lung function across the range of small-opacity profusion. These findings address a long-standing question in occupational medicine and point to the importance of medical surveillance and respiratory disease prevention in this workforce.

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ABBREVIATIONS: CWHSP = Coal Workers' Health Surveillance Program; CWP = coal worker's pneumoconiosis; ECWHSP = Enhanced Coal Workers' Health Surveillance Program; FEV₁ % = FEV₁ % predicted; FVC % = FVC % predicted; ILO = International Labor Organization; MSHA = Mine Safety and Health Administration; NIOSH = National Institute for Occupational Safety and Health; PEL = permissible exposure limit; PMF = progressive massive fibrosis

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In 1969, the US Congress passed the Federal Coal Mine Health and Safety Act (Coal Act) “to prevent death and serious physical harm, and to prevent occupational disease” caused by work in the nation’s coal mines.¹ Since 1972, the permissible exposure limit (PEL) for respirable coal mine dust has been 2 mg/m³. This enforceable standard was adopted to protect underground coal miners from disability and premature mortality that accompanies severe coal worker’s pneumoconiosis (CWP).^{2,3} In the decades following enactment of the PEL there was a clear and substantial decline in the prevalence of CWP among active miners as reported by the National Institute for Occupational Safety and Health (NIOSH) Coal Workers’ Health Surveillance Program (CWHSP), but a resurgence of the disease has been observed, most notably in the central Appalachian region.⁴⁻⁸

During congressional hearings before passage of the Coal Act, scientists and lawmakers acknowledged that implementation of the 2 mg/m³ PEL, which had been derived from British research, would not completely prevent the occurrence of new cases of CWP⁹; simple CWP (International Labor Organization [ILO] small-opacity profusion $\geq 1/0$ in the absence of large opacities on chest radiograph) would continue to occur among long-tenured miners, although at a lower prevalence.¹⁰ At the time, most available evidence suggested that, as long as miners worked under dust conditions consistent with the 2 mg/m³ PEL, there would be many fewer newly incident simple CWP cases, simple CWP cases would not be expected to advance to progressive massive fibrosis (PMF), and miners would no longer become disabled or suffer premature mortality as a result of the disease.^{3,10} Officials focused regulatory and

public health efforts on preventing PMF among coal miners, based on the widespread belief that, in contrast with PMF, simple CWP was not associated with clinically significant lung function impairment. Research from the UK’s Medical Research Council Pneumoconiosis Research Unit during the 1950s and 1960s generally reported no association between increasing profusion of small opacities and worse lung function among those with simple CWP,¹¹⁻¹³ as did later studies of US coal miners.¹⁴⁻¹⁷ Medical textbooks have tended to perpetuate the early view,¹⁸⁻²¹ despite much of that early work having been called into question,^{22,23} and a number of international studies of coal miners in Britain,^{24,25} China,²⁶ South Africa,²⁷ and Turkey²⁸ reporting lung function impairment among coal miners with simple CWP.

A large body of evidence demonstrates dose-response relationships of cumulative coal mine dust exposure with lung function impairment and also with small-opacity profusion.²⁹⁻³⁷ However, the association between profusion of small opacities in simple CWP and lung function has not been thoroughly investigated in US coal miners. A study using data from the NIOSH Enhanced Coal Workers’ Health Surveillance Program (ECWHSP) identified similar geographic distributions of spirometric abnormalities (findings below lower limits of normal using US population prediction equations) and radiographic CWP, in addition to associations between small-opacity profusion category and certain lung function measures.³⁸ We have expanded this work, using four additional years of data, by examining the relationship of radiographic profusion of opacities by subcategory with lung function in active and former underground coal miners with simple CWP.

Materials and Methods

In the ECWHSP, NIOSH staff visit mine sites or nearby communities to provide examinations at no cost to coal miners. The emphasis of the ECWHSP has been active coal miners, but former miners are welcome to participate. As a surveillance program, the ECWHSP has been granted a nonresearch designation by the NIOSH Institutional Review Board (11-DRDS-NR03). Trained technicians obtain written informed consent from participating miners, collect work histories, take posterior-anterior chest radiographs, and administer spirometry.³⁹ Each chest radiograph is independently classified by a minimum of two physicians, at least one of whom is certified by NIOSH as a B Reader.⁴⁰ All radiographs first classified by an A or B Reader are then submitted by NIOSH to a B Reader. If there is agreement between the two classifications, the result is final. If not, NIOSH requests a third classification from a panel of B Readers. If there is not agreement among the three classifications, two additional independent B Reader classifications are obtained, and the final determination is the median profusion category of the five classifications. Lung parenchymal abnormalities consistent with CWP are classified according to ILO guidelines.⁴¹ A final determination

of small-opacity profusion subcategory 1/0 or greater (range: 0/– to 3/+) or large-opacity category A, B, or C is considered evidence of CWP.⁴² Lung function testing is conducted using a SensorMedics dry-rolling seal volume spirometer (SensorMedics Italia) integrated with Occupational Marketing Inc spirometry software (OMI). Spirometry calibration, performance, and results are interpreted according to American Thoracic Society and European Respiratory Society guidelines.^{43,44} Reference values and lower limits of normal for FEV₁, FVC, and FEV₁/FVC are calculated using sex and race-specific reference equations derived from the third National Health and Nutrition Examination Survey.⁴⁵ Measured height (without shoes), measured weight, age, underground mining tenure, and smoking status (current, former, never) are recorded for each participant.

We evaluated differences in miner characteristics and lung function values (FEV₁ % predicted [FEV₁ %], FVC % predicted [FVC %], and FEV₁/FVC) across the range of profusion subcategories for small opacities. We used SAS software version 9.3 (SAS Institute Inc) to fit linear regression models, with lung function values as continuous outcomes and profusion subcategory as an ordinal predictor, while controlling for smoking

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