ECOLOGIC ANALYSIS OF COAL WORKERS PNEUMOCONIOSIS MORTALITY IN ILLINOIS

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INTRODUCTION

In a pneumoconioses surveillance system, states collect data on numbers of cases and calculate rates by geographical areas such as countries. Exposure data are often collected at the county level, especially when person-specific data are not available. Associations between disease and exposure at the county level can be explored through ecologic analysis. The distinguishing feature of ecologic studies is that the group (i.e., county) rather than the individual is the unit of analysis. Statistical methods employed in the analysis of such data include correlations and regression.

Ecologic designs have often been used to study diseases of unknown etiology. For example, intercounty differences in mortality from non-Hodgkin's lymphoma have been correlated with environmental and industrial exposures at the county level.[1] While the etiologies of pneumoconioses are known, ecologic studies may identify new sources of dust exposure. This study explores the ability of ecologic analysis to statistically detect an association between coal production and CWP mortality in the state of Illinois. If the technique is able to detect a known association, it may prove useful in generating new hypotheses regarding industries associated with pneumoconioses.

METHODS

All cases of CWP from 1980–1984 were identified through a review of computer tapes of Illinois death certificates. Cases were coded with International Classification of Disease (Ninth Revision) code 500 as the underlying or contributing cause of death. Five-year crude rates for white males were calculated by county. Denominators were derived from the 1980 Census and county population estimates from the non-census years, for white males age 35 and over.[2]

Two indices of coal mining in Illinois counties in 1965 were used as surrogate measures of exposure to coal dust.[3] The first index, tons of coal mined, was a direct measure of production. The second index, the average tons of coal mined per worker per 8-hour day, was a measure of mine productivity. These two indices were further subdivided into underground, surface and total coal mining. Exposure data from 1965 were selected to allow for a 15 to 20 year lag period between first exposure and death.

The association between CWP mortality and coal mining was analyzed using weighted least-squares regression. Six different univariate regression models were fitted to the data. Counties with both zero death and zero production were excluded from each of these analyses. Rates were log-transformed and weighted by the inverse of the square roots of the denominators, in order to meet the assumptions of regression analysis. The SAS Regression Procedure program was used to perform the analysis.[4]

RESULTS

There were 367 white male CWP deaths from 1980 to 1984, 7 deaths among black males and 1 among white females. Mortality rates ranged from zero in 61 counties to 322.4/100,000/5 years in Franklin County, with a state average of 3.7/100,000/5 years. Forty-six out of a total 102 Illinois counties met the study criteria of having either CWP mortality in 1980–1984 or coal production in 1965. Forty-one of these counties reported CWP deaths and 5 produced coal but reported no CWP deaths.

Seven counties had underground but no surface mining, 9 had surface but no underground mining, 6 had both types and 24 had neither. Non-zero values for 1965 underground coal production ranged from 16,731 tons in Henry County to 6,182,282 tons in Franklin County, with a state mean of 1,766,958 tons for coal producing counties. Non-zero surface production ranged from 1,938 tons in Johnson County to 8,220,858 tons in Fulton County, with a state mean of 1,047,647 tons. Underground mine productivity in tons/worker/day was highest in Franklin County (23.0) and lowest in Henry County (9.1) with a mean of 18.1 for coal-producing counties. Surface mine productivity was highest in Knox County (56.1) and lowest in Gallatin County (14.2) with a state mean of 34.3 tons/worker/day.

Table I presents the results of linear regressions of the exposure indices on the log of CWP mortality rates. CWP mortality was significantly ($p \geq .005$) associated with tons of underground, surface and total production. In the underground models, production explained 51% of the variability in CWP mortality rates, while in surface models, production explained 18%. Corresponding values were lower with productivity as the surrogate exposure variable: 22% for underground tons/worker/day and 9% for surface tons/worker/day. The associations between underground, surface and total tons/worker/day and CWP mortality were also statistically significant ($p \geq .05$).

In Figure 1, the CWP mortality rates are plotted on a log scale against the 1965 underground tons produced. Franklin County stands out as having the highest CWP mortality and

Table I

Linear Regression of Log CWP Mortality Rates on Selected Measures of Coal Mine Production in Illinois

Variable	B_0	B_1	p	r^2
Underground				
Tons	1.036	7.223×10^{-7}	.0001	.51
Tons/worker/day	1.084	6.790×10^{-5}	.0016	.22
Surface				
Tons	1.122	3.497×10^{-7}	.0032	.18
Tons/worker/day	1.124	2.100×10^{-5}	.0498	.09
Total				
Tons	0.879	4.492×10^{-7}	.0001	.55
Tons/worker/day	0.992	2.340×10^{-5}	.0041	.17

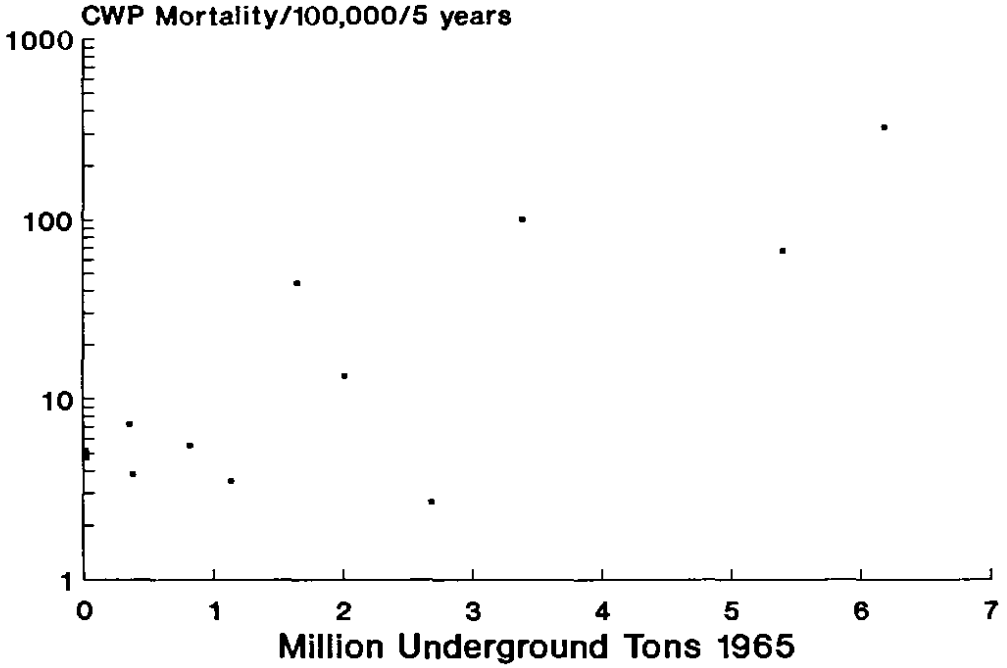

Figure 1. CWP mortality by 1965 underground tons.

1965 underground mine production. Other notable characteristics of Franklin County are that it had the highest cumulative coal production of all Illinois counties from 1882 to 1965, and all its mines are underground.[3]

DISCUSSION

This study demonstrates that ecologic analysis is able to detect the known association between CWP mortality and exposure to coal dust in underground mines. As expected, CWP mortality was more strongly associated with underground mining than surface mining. The significant association of surface mining and CWP mortality may be due to the concurrence of surface and underground mining in counties of high production and high CWP mortality. For example, Williamson County, which had the second highest mortality rate in the state (100.3/100,000/5 years), produced more than 3 million tons in surface mines and more than 3 million tons in underground mines in 1965.

While surface mining was statistically associated with CWP mortality, we cannot determine whether any individual death was a result of exposure in surface mines without obtaining individual work histories. Inferences about individuals drawn from data on groups are susceptible to the "ecologic fallacy."[5]

A commonly used measure of dust exposure is the product of the dust concentration and duration of exposure. Surrogate exposure measures used in ecologic studies should be close approximations of the workers cumulative dust exposure. The type of data available at the county level often determines what surrogate variables will be used in an analysis, and conceivably, a disease-exposure association may be missed when a poor surrogate variable is selected. In this study, county coal production and mine productivity were both significantly associated with CWP mortality. Productivity, however, was a poorer predictor of mortality than actual production in underground, surface and total mining models. One possible explanation for this result is that high productivity by definition reflects high production relative to person-work time. Decreased person-work time may mean less exposure to coal dust and thus lower CWP mortality rates.

Several biases may be present in this study. Measurement bias may result from the use of cross-sectional exposure data from just one year, since that year could be atypical for coal production in any given county. Age confounding may occur because rates are not age-adjusted. We did not have access to national multiple-cause CWP mortality rates, and rates based solely on underlying cause would have missed 72% of all CWP deaths in Illinois. Another potential confounder, intercounty migration from mining to non-mining areas, would weaken the association between coal mining and CWP mortality. Migration may also occur from one type of mining to another, both within and between counties, although the effects of this are more difficult to predict. Other unmeasured variables which may confound or modify the disease-exposure relationship include mining techniques (i.e., longwall vs. panel) and dust control.

A major advantage of ecologic studies is that they do not require primary data collection but may rely instead on preexisting sources of data. For ecologic studies to be feasible, there must be a sufficient number of disease events at the group level, as well as suitable exposure data. For example, Illinois was the fifth highest coal-producing state in the U.S. as of 1984, and has the largest bituminous coal resources in the country. Thus, Illinois has incurred substantial CWP morbidity and mortality, and data on coal production is easily obtained.

As an adjunct to simple geographic mapping, ecologic analysis is useful for identifying predictor variables of CWP mortality in Illinois. In addition to examining the data cross-sectionally, CWP mortality trends can be studied through time-series analysis in future research. Ecologic analysis may prove useful in identifying predictor variables of disease outcomes for other pneumoconioses.

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