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Research Article

Heart Disease Mortality in Appalachian Coal Mining Counties

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Abstract

Background: Earlier examinations of mortality patterns in West Virginia found higher total mortality in coal mining compared to non-coal mining counties. The objective is to further explore these findings and determine whether heart disease mortality in West Virginia is associated with coal mining or other factors.

Methods: West Virginia county Specific Standardized Mortality Ratios (SMRs) were calculated and base (sex, age group and time period-adjusted) and covariate-adjusted (base + income, smoking, and obesity) SMR models were computed for cumulative total, surface, and underground coal production. Models were also stratified by dichotomous versions of income, smoking, and obesity.

Results: Median income, obesity, and smoking were all found to be statistically significant predictors of heart disease SMRs and were also found to have statistically significant interactions with coal production. Specifically, SMRs generally increased as median income decreased in mining counties, and SMRs generally increased as obesity increased in mining counties. The same relationships were not evident in non-mining counties. Additionally, SMRs were elevated in the highest two quartiles of coal production in counties with high smoking prevalence.

Conclusion: SMRs for heart disease were elevated in the highest levels of total, surface and underground coal production compared to the state population. Further research should examine the relationship between coal-mining and heart disease at the individual level.

Introduction

An earlier examination of mortality patterns in West Virginia coal mining counties compared to Appalachian non-coal mining counties, found statistically significantly higher total mortality and some specific causes of death in coal mining compared to non-coal mining counties [1]. However, the findings for total mortality did not appear to be associated with coal production [2].To further explore these findings and adjust for potential confounding factors, county-level information on tons of underground, surface, and total coal mined, economic, and health factors were collected. Of particular interest was heart disease, the leading cause of death in the United States, which accounts for approximately 610,000 deaths annually [3]. The risk of death from heart disease is highly associated with obesity, hypertension, and high cholesterol levels among other factors [4]. In addition, there has been some evidence for the role of environmental risk factors, including coal production, on heart disease [5,6].In Appalachia, a region including all of West Virginia, Hendryx found an association with higher coal production (>four million tons) and increased total and chronic heart disease mortality in males and females in 2000-2004 after adjustment for demographic factors, smoking, education, access to health care, poverty, being in the South, and urban-rural continuum code [6].

The purpose of this analysis is to examine the association between all heart disease mortality from 1962-2009 and cumulative total, surface, and underground coal production, with and without control for covariates.

Methods

Identification of Coal Mining and Non-Coal Mining Counties

Details regarding the methodology have been presented elsewhere [1,2]. In brief, WV coal mining and non-coal mining counties were identified using data from the Appalachian Region Commission and Energy Information Agency [7,8]. Cumulative total, surface, and underground tons of coal was calculated for each coal mining county. Information from national sources was collected on county-level potential confounding factors including: median income [9], smoking [10] and obesity rate [11]. Smoking prevalence was defined as male and female adults 18 years and over who currently smoke, provided by the National Cancer Institute Small Area Estimates.

The Mortality and Population Data System (MPDS) [12] generated the mortality rates for the *a priori* cause of interest: all heart disease (International Classification of Disease (ICD) 9th revision codes 390-398, 402, 404, 410-429). In MPDS, death records and mortality rates were categorized and linked with the corresponding population data to form death rates specific for five-year age groups, five-year time periods (1962-2009), sex, geographic location (county), and cause of death.

Statistical Analyses

County specific Standardized Mortality Ratios (SMRs) were calculated by applying West Virginia state heart disease mortality rates to county populations. Graphical methods were used to show relationships between coal production, obesity, median income, and SMRs. Plots of obesity by SMR and median income by SMR included fitted lines from the regression of SMR on the covariate, to capture trends in mining and non-mining counties. We used negative binomial regression to estimate SMRs [13] of the form: log [E (observed deaths)] = log (expected deaths) + β_0 + $X_i\beta$, where X_i is the matrix of covariates and β is the vector of regression coefficients. Negative binomial regression was used due to over dispersion in Poisson models, which was confirmed via likelihood ratio tests and the Pearson chi-square dispersion statistic. Base models were fit for categorized (four-level) coal for total, surface, and underground coal, which included age, sex, and year. Adjusted models also included median income, obesity, and smoking. Additional models were fit stratified by dichotomous versions of obesity, median income, and smoking due to evidence of interactions. Counties were considered to have a low obesity prevalence if less than or equal to the state average (28.8%), a low median income if less than or equal to the state average ($34,447), and a low smoking prevalence if less than or equal to the state average (33.1%).

Results

Figure 1 shows the county specific SMRs, where red counties indicate statistically significantly higher number of deaths from heart disease than expected, and green counties indicate statistically significantly lower number of deaths than expected. 13 of 55 counties had statistically significantly higher number of deaths than expected, and 11 of these 13 counties are mining counties.

Figure 2 shows a plot of SMR by total coal production for the West Virginia mining counties with 95% confidence intervals. Mingo County has the highest SMR (126.2, 95%CI 123-129) and has the second highest total coal production (285 million short tons). Boone County has the highest total coal production (447 million short tons) with a not statistically significant SMR of 98.2 (95%CI 95-101).

Figure 3 is a plot of SMR by median income for coal and non-coal mining counties. A fitted line for coal mining counties shows a negative relationship. As median income decreases, SMRs are generally increasing. A fitted line for non-coal mining counties shows a positive association indicating that SMRs increase as median income increases, although the highest SMR in a non-coal mining county is 106.4 (Hancock, WV).

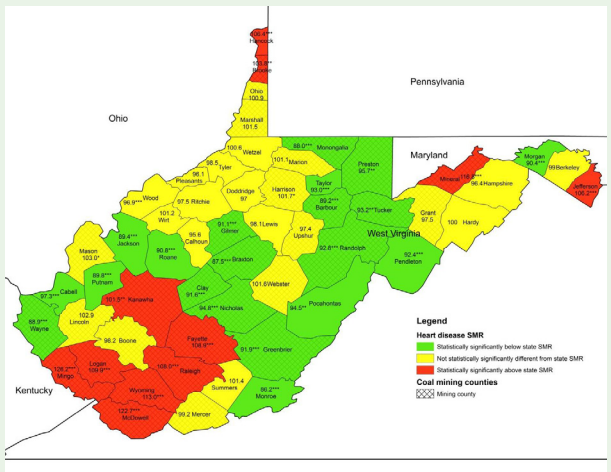

Figure 1: Heart Disease SMR for WV Counties by Coal Mining Status.

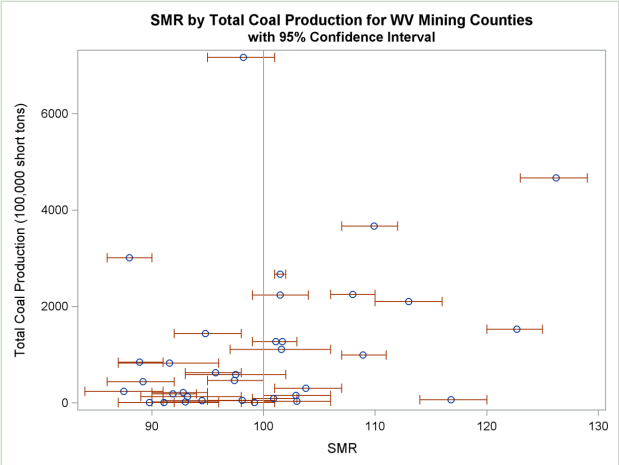

Figure 2: Heart Disease SMR by Total Coal Production.

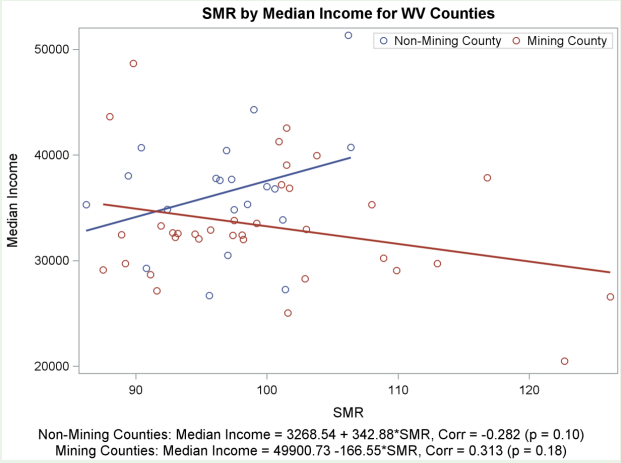

Figure 3: Heart Disease SMR by Median Income for WV Counties.

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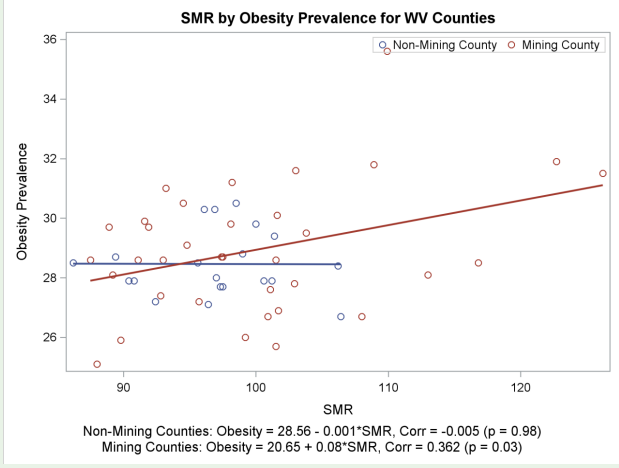

Figure 4: Heart Disease SMR by Obesity for WV Counties.

Figure 4 shows SMR by obesity for coal mining and non-coal mining counties. A fitted line shows SMR increasing as obesity prevalence increases. There is no apparent relationship between SMR and obesity in non-coal mining counties. Both plots indicate a potential interaction with coal production.

Table 1 shows the SMRs for all three types of coal mining stratified by median income. Statistically significant mortality excesses existed in both the low median income counties and the high median income counties. SMRs for total and underground coal in low median income counties exhibited a backwards "J" shape, where SMRs dropped in the second coal level and increased in the third and fourth. For high median income counties, the highest level of total coal mining had a 3% excess; while for low median income counties, the highest level of total coal mining had a 17% excess of heart disease mortality. Statistically significant excesses in the second and fourth levels of surface coal ranged from 5 to 7% in high median income counties, while statistically significant excesses in the third and fourth levels of surface coal ranged from 6 to 11% in low median income counties.

Table 1: All Heart Disease SMRs by Type of Coal Mining, Stratified by Median Income.

Coal (Short Tons)		Median Income < 34,447				Median Income ≥ 34,447			
		SMR	95%	CI	*P*-value	SMR	95%	CI	*P*-value
Total	No Coal	1.00			<0.01	1.00			<0.01
	< 2,279,047	1.01	0.97	1.04		1.03	1.00	1.07	
	2,279,047 - < 9,467,637	0.96	0.93	1.00		1.04	1.01	1.07	
	9,467,637 - < 31,600,000	1.05	1.01	1.08		1.05	1.02	1.08	
	≥ 31,600,000	1.17	1.12	1.21		1.03	1.00	1.05	
Surface	No Coal	1.00			<0.01	1.00			<0.01
	< 615,391.5	1.00	0.97	1.03		0.97	0.94	1.00	
	615,391.5 - < 1,964,431	1.00	0.97	1.04		1.07	1.05	1.10	
	615,391.5 - < 1,964,431	1.06	1.03	1.10		1.00	0.98	1.03	
	≥ 9,484,500	1.11	1.08	1.15		1.05	1.02	1.09	
Underground	No Coal	1.00			<0.01	1.00			<0.01
	< 2,423,829	1.01	0.97	1.04		1.03	1.00	1.07	
	2,423,829 - < 7,917,622	0.99	0.96	1.03		1.04	1.01	1.07	
	7,917,622 - < 28,700,000	1.02	0.98	1.05		1.05	1.01	1.09	
	≥ 28,700,000	1.17	1.12	1.21		1.03	1.01	1.05	

The highest level of underground coal had statistically significant mortality excesses of 3% and 17% for high median income and low median income counties, respectively.

Table 2 shows SMRs for all three types of coal separately for high obesity prevalence counties (prevalence ≥ 28.8%) and low obesity prevalence counties (prevalence < 28.8%). The highest two levels of total coal production had statistically significant excesses in both the high and low obesity prevalence counties. SMRs for total coal in both high and low obesity prevalence counties followed a backwards "J" shape, with SMRs declining in the second level of coal and increasing in the third and fourth. SMRs for underground coal in the low obesity prevalence counties followed a "U" shape, with SMRS declining in the second and third levels of coal and increasing in the fourth. SMRs for the highest two levels ranged from 1.03 to 1.05 in low obesity prevalence counties and ranged from 1.06 to 1.16 in high obesity prevalence counties. Results were similar for underground coal production. Statistically significant SMRs for the second and fourth levels of surface coal in low obesity prevalence counties were 1.07 and 1.05, respectively. Statistically significant SMRs for the third and fourth levels of surface coal in high obesity prevalence counties were 1.11 and 1.10, respectively.

Table 2: All Heart Disease SMRs by Type of Coal Mining, Stratified by Obesity Prevalence.

Coal (Short Tons)		Obesity ≥ 28.8%				Obesity < 28.8%			
		SMR	95%	CI	*P*-value	SMR	95%	CI	*P*-value
Total	No Coal	1.00			<0.01	1.00			<0.01
	< 2,279,047	1.01	0.98	1.05		1.03	0.99	1.05	
	2,279,047 - < 9,467,637	0.99	0.95	1.02		1.04	0.97	1.01	
	9,467,637 - < 31,600,000	1.06	1.03	1.09		1.05	1.01	1.06	
	≥ 31,600,000	1.16	1.12	1.20		1.03	1.03	1.08	
Surface	No Coal	1.00			<0.01	1.00			<0.01
	< 615,391.5	1.03	0.99	1.08		0.98	0.96	1.00	
	615,391.5 - < 1,964,431	0.99	0.95	1.03		1.07	1.05	1.10	
	615,391.5 - < 1,964,431	1.11	1.07	1.15		1.02	1.00	1.04	
	≥ 9,484,500	1.10	1.07	1.13		1.05	1.02	1.09	
Underground	No Coal	1.00			<0.01	1.00			<0.01
	< 2,423,829	1.01	0.98	1.05		1.02	1.00	1.05	
	2,423,829 - < 7,917,622	1.02	0.99	1.05		1.00	0.97	1.03	
	7,917,622 - < 28,700,000	1.06	1.03	1.10		1.00	0.98	1.03	
	≥ 28,700,000	1.16	1.12	1.21		1.05	1.03	1.08	

Table 3 shows SMRs for all three types of coal separately for high smoking prevalence counties (≥33.1%) and low smoking prevalence counties (<33.1%). In low smoking prevalence counties, SMRs exhibited no clear trend and were not significant for total or underground coal. In counties with high smoking prevalence, SMRs for all forms of coal were globally significant. This was primarily driven by statistically significant elevations in the third and fourth quartiles ranging from 8% to 16%.

Discussion

This study is the first to examine heart disease mortality rates in coal mining areas of West Virginia over the almost 50 year period of 1962-2009. Environmental risk factors have been implicated in chronic disease morbidity and mortality. Previous studies have indicated an association between coal mining activity and chronic cardiovascular, lung, and kidney disease, particularly in the

Table 3: All Heart Disease SMRs by Type of Coal Mining, Stratified by Smoking Prevalence.

Coal (Short Tons)		Smoking ≥ 33.1%				Smoking < 33.1%			
		SMR	95%	CI	*P*-value	SMR	95%	CI	*P*-value
Total	No Coal	1.00			<0.01	1.00			<0.70
	< 2,279,047	1.05	1.01	1.05		1.00	0.98	1.03	
	2,279,047 - < 9,467,637	0.98	0.95	1.02		0.99	0.97	1.01	
	9,467,637 - < 31,600,000	1.11	1.08	1.09		1.00	0.97	1.02	
	≥ 31,600,000	1.16	1.13	1.20		1.01	0.98	1.04	
Surface	No Coal	1.00			<0.01	1.00			<0.01
	< 615,391.5	1.00	0.97	1.04		0.98	0.96	1.00	
	615,391.5 - < 1,964,431	1.04	0.99	1.08		1.04	1.02	1.16	
	615,391.5 - < 1,964,431	1.13	1.09	1.16		0.97	0.95	1.00	
	≥ 9,484,500	1.12	1.09	1.15		1.04	1.01	1.08	
Underground	No Coal	1.00			<0.01	1.00			<0.14
	< 2,423,829	1.05	1.01	1.10		1.00	0.98	1.03	
	2,423,829 - < 7,917,622	1.04	1.01	1.07		0.99	0.97	1.02	
	7,917,622 - < 28,700,000	1.08	1.05	1.11		0.98	0.95	1.01	
	≥ 28,700,000	1.16	1.13	1.19		1.02	0.99	1.04	

Appalachian region [6,14]. O'Toole et al. reviewed the evidence on heart disease and environmental risk factors and concluded that environmental stress is an important determinant for risk [15]. Pope et al found an association between cardiovascular mortality and low levels of fine particulate matter [16]. Hendryx [6] investigated mortality rates from 2000-2004 for total, chronic, and acute heart disease in relation to tons of coal mined. He found 6-7% excesses in total heart disease for males and females with production greater than 4 million tons. He found higher risks for chronic heart disease, but reduced risk for acute heart disease mortality. This study found similar all heart disease mortality excesses (SMRs 1.05-1.07) in the highest levels of total, surface, and underground coal production after adjusting for age, sex, year, median income, smoking, and obesity (data not shown).

The study also found interesting relationships between obesity, median income, smoking, coal production, and heart disease mortality. In general, mining counties with lower median income are associated with higher SMRs. In fact, stratifying the models by median income indicated that the effect of the highest level of coal production, regardless of type, was greater in low median income counties (median income < 34,447) compared to high median income counties. Mining counties with higher obesity prevalence were also found to be generally associated with higher SMRs. Specifically, the effect of the highest level of all three forms of coal production was greater in counties with a high obesity prevalence (≥ 28.8%) compared to those with a low obesity prevalence. Additionally, the effect of the highest two quartiles of coal production was found to be greater in counties with high smoking prevalence (≥ 33.1%). In counties with low smoking prevalence, there is either a flat or inconsistent pattern with coal. These findings may indicate that the associations between environmental exposures and mortality are more pronounced among those at highest risk due to personal risk factors, such as obesity and smoking, or poor socioeconomic status. It is also interesting to note that most of the counties with statistically significantly elevated SMRs are geographically located in the southern portion of West Virginia. This is also an area of the state with high levels of coal production and high levels of obesity.

Talbott et al. investigated the relationship between county-level Circulatory Hospitalization Rates (CHR) in coal and non-coal mining counties of West Virginia, coal production, coal employment, and sociodemographic factors. After adjustment for smoking, education, and income, neither total surface, nor underground coal production was significantly related to rate of hospitalization for circulatory disease. Their findings underscore the significant role sociodemographic and behavioral factors play in the health and wellbeing of coal mining counties [17].

This study has several strengths. West Virginia mortality and coal production data from a 50 year period allow for a better understanding of the impact of coal over time. Quartiles of coal production, rather than a dichotomized level of coal, were used to better examine if any trend existed in mortality excesses compared to coal production. The statistical significance of obesity, median income, and smoking in relation to heart disease mortality was also assessed. Despite the advantages, this study does have some limitations. Only group-level data were used for all covariates and for coal, so a causal effect between mortality and cumulative coal exposure could not be evaluated. Point in time estimates for obesity, smoking, and median income were used from the early 2000s, which may not have prevailed historically. Controlling for some important heart disease risk factors, such as hypertension and cholesterol levels was not possible. Finally, no formal adjustment was made for the multiple comparisons performed, so some statistically significant findings may simply be due to chance. Future research should examine the relationship between coal-mining, obesity, income, and heart disease mortality at the individual level.

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