Comparison of Mortality Rates Between Appalachian Coal Mining Counties with Non-Coal Mining

Jeanine M. Buchanich
Department of Biostatistics, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania

Evelyn O. Talbott
Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania

Ada O. Youk
Department of Biostatistics, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania

Andrew N. Potter
Department of Biostatistics, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania

Lynne P. Marshall
Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania

ABSTRACT

Recent studies have indicated that adverse health outcomes occur at higher rates in Appalachia, particularly in West Virginia. However, conflicting evidence has been found regarding whether these disparities are due in part to coal mining in Appalachia or to other social, economic, or health factors. In this study, we computed age-adjusted mortality rates and the associated confidence intervals for multiple causes of death. These were then used to conduct a graphical analysis comparing the mortality rates for the coal mining and non-coal mining counties. For all cause mortality rates, coal mining counties had higher mortality rates than non-coal mining counties. However, there are no consistent trends for across the specific causes of mortality in this study. Additional studies are needed to refine the nature of these findings.

INTRODUCTION

Recent studies have indicated that adverse health outcomes, including mortality, occur at higher rates in the Appalachian region of the US (Hendryx, et al. 2008, Wingo, Tucker et al. 2008, Hendryx 2009, Christian, et al. 2011, Esch and Hendryx 2011, Borak, et al. 2012). However, conflicting evidence has been found regarding whether these disparities are due in part to coal mining in Appalachia (Hendryx, et al. 2008, Hendryx 2009, Hendryx and Ahern 2009, Hendryx, et al. 2010, Esch and Hendryx 2011, Borak,et al. 2012). In an effort to compare mortality in coalmining versus non-coal mining counties, we performed an ecological evaluation of total and select cause-specific mortality rates of West Virginia (WV) coal mining counties compared to mortality in Appalachian non-coal mining counties.

METHODS

We conducted descriptive and statistical analyses of the total and select cause-specific mortality rates in WV coal mining and non-coal mining counties. We attempted to control for the possible confounding of socioeconomic status (SES) by selecting control counties for comparison based on county-to-county frequency matching. We controlled for age, time, race, and sex by utilizing age-time-race-specific mortality rates in our statistical comparisons. This study was exempt from review by the University of

Pittsburgh Institutional Review Board because it only involved aggregate statistical analyses of mortality data.

Identification of WV Mining Counties and Appalachian Comparison Counties

We used ever/never coal mining status in 1994 as a proxy for the whole study period, hypothesizing that areas of recent coal mining also have historical coal mining (Energy Information Agency 1994). We defined Appalachian counties as those indicated by the Appalachian Region Commission (ARC) (Appalachian Regional Commission), a regional economic development agency established by an act of Congress in 1965.

Before creating matched pairs of WV coal mining counties and a non-mining county, we gathered demographic information for all counties in WV from Census 2000 DP-3: Profile of Selected Economic Characteristics and QT-P33: Income in 1999 by Selected Household, Family, and Individual Characteristics for median income (U.S. Census Bureau). We also gathered mining status in 1994 (Energy Information Agency 1994) and the same demographic data (U.S. Census Bureau) for Pennsylvania, Maryland, Virginia, North Carolina, Tennessee, Kentucky, and Ohio; all of the Appalachian non-coal mining counties in these states, plus WV, became our pool of potential matches.

The matching process was conducted iteratively. The first step was to calculate an income range (median income ±5%) for each coal mining and non-coal mining county eligible for inclusion. For each coal mining county, potential non-coal mining matches were identified by median income and geographic proximity, with counties within WV given higher priority. Next, we chose the non-coal mining county with the nearest median income to the coal mining county as a candidate match. We did not match adjacent counties with the exception of Mineral County (Hampshire County) and Marshall County (Jackson County).

Generation of Mortality Rates

We used the Mortality and Population Data System (MPDS) (Marsh, Youk et al. 2005) to generate the mortality rates and standard errors for the causes of interest. The MPDS contains the underlying cause of death code (using International Classification of Diseases (ICD) four-digit codes in effect at the date of death) for all persons who died of cancer causes in the US between 1950 and 2007 and 1960–2007 for non-cancer causes, including total mortality. The specific causes of death evaluated were: total mortality (International Classification of Disease (ICD) 9th revision codes 001–999), mortality from all cancers (ICD 9th revision codes 140–209), respiratory system cancer (ICD 9th revision codes 160–165), kidney cancer (ICD 9th revision code 189), diabetes mellitus (ICD 9th revision code 250), heart disease (ICD 9th revision codes 390–398, 402, 404, 410–429), cerebrovascular disease (ICD 9th revision codes 430–438), non-malignant respiratory disease (ICD 9th revision codes 460–519), and all external causes (ICD 9th revision codes 800–949).

Data Analysis

We performed a graphical analysis of the age-adjusted mortality rates for males and females in the coal mining counties as compared to the non-coal mining counties for 5-year time periods from 1950–2007 (cancer causes) or 1960–2007 (non-cancer causes). Graphs were created for each cause of death of interest and included both the age-adjusted mortality rate and its associated 95% confidence interval (CI) for each time period; also shown for select causes of death are detailed tables with the mortality rate and 95% CI for each time period. For each time period, the rates for the coal mining counties and non-coal mining counties were considered statistically significantly different if the 95% confidence intervals were not overlapping. These comparisons do not account specifically for the matching of non-coal mining county to coal mining county, but instead aggregate all of the 31 coal mining and non-mining counties.

RESULTS

The figures and tables show the age-race-adjusted mortality rates per 100,000 people in the coal mining counties as compared to the non-coal mining counties for each of the five year time periods. As seen in Figure 1, all cause mortality rates are statistically significantly higher in coal mining counties compared to non-coal mining counties across all time periods for males and females. For all cancer mortality (Figure 2), rates for males in both groups reach a peak in the late 1980s/early 1990s and then begin declining; rates for females in both groups appear more stable. Table 1 shows that male rates in the coal mining counties are statistically significantly higher from the 1960s through the 1980s but are not consistently statistically significantly higher from the 1990s through the present. For females, all cancer mortality is statistically significantly higher in the 1980s and 1990s, although appears to be converging in the most recent time period examined.

The patterns for all respiratory system cancer mortality (Figure 3) and all respiratory system cancer mortality are similar to the trends for all cancer, although the rates in women appear to be rising through the 1990s and 2000s.

Figure 4 shows that the patterns for kidney cancer are less consistent, with more variability and elevations by the non-coal mining counties in both males and females. The increased variability is due to the small number of kidney cancer cases in the counties involved, and is reflected in Table 2 which shows no statistically significantly different confidence intervals. Table 2 also reveals occasionally higher mortality rates in non-coal mining counties, especially among males. Rates for males in both groups are rising while rates for women seem to have remained stable.

Mortality rates for heart disease (Figure 5) are decreasing in both non-coal mining and coal mining counties, although coal mining county rates are consistently statistically significantly higher than non-coal mining counties.

Stroke mortality (Figure 6) is declining for both males and females in both coal mining and non-coal mining counties. As shown, non-coal mining rates for males and females are statistically significantly higher compared to the coal mining counties through the 1970s, when non-coal mining remains higher although the difference is no longer statistically significant. Table 3 emphasizes the dramatic reduction in mortality rates for stroke and, in the 2005–2007 period, rates for all four groups are virtually identical.

Diabetes mortality (not shown) showed a great deal of variability, with excesses in both non-coal mining and coal mining counties for males and females, although none of the differences were statistically significant until the 1990s. From that point forward, coal mining counties had statistically significantly higher rates for males and females. The rates for all external causes (not shown) are nearly identical between the coal mining and non-coal mining counties with no statistically significant differences

Rates for non-malignant respiratory disease (Figure 7) have remained relatively stable over time for males and females. As shown in Table 4, rates for males are statistically significantly higher in coal-mining counties throughout all time periods. For females, rates are statistically significantly higher in the coal mining counties in 1975–79 and from 1985–94; from 1960–69 rates for females in the non-coaling mining counties were not statistically significantly higher.

DISCUSSION

This study found limited evidence of elevated total and cause-specific mortality rates when comparing coal mining to non-coal mining counties in Appalachia. For several causes of death, coal mining counties had statistically significantly higher mortality rates compared to non-coal mining counties. Total mortality was statistically significantly higher across all time periods for men and women in coal mining compared to non-coal mining counties. While Hendryx and Ahern (Hendryx and Ahern 2009) also found higher mortality among coal-mining counties in Appalachia, their comparison group was non-mining, non-Appalachia which may not account for factors and culture unique to Appalachia (Lengerich, et al. 2004, Lengerich, et al. 2006). We also found higher rates of heart disease in coal

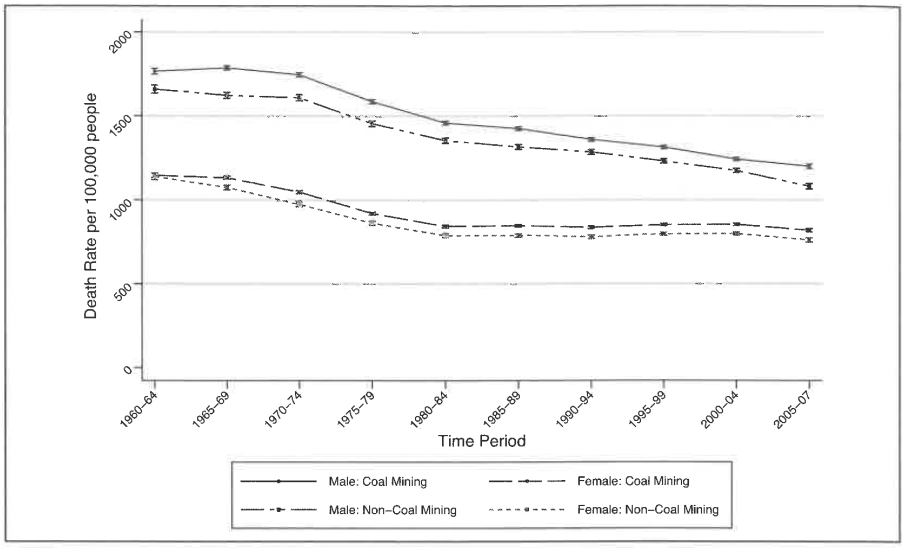

Figure 1. All cause age-race adjusted mortality rates males and females in the West Virginia coal mining counties and the income matched non-coal mining Appalachian counties with the 95% confidence intervals plotted for each time period

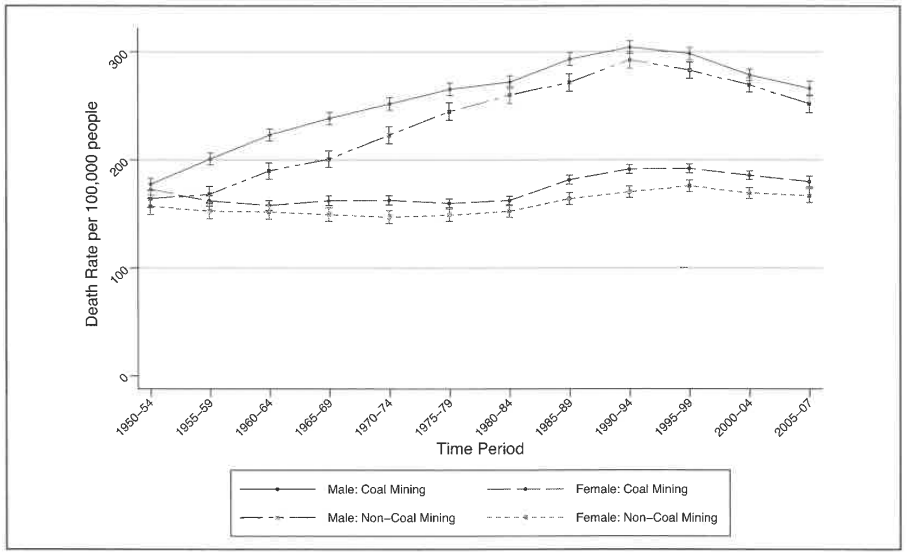

Figure 2. All cancer age-race adjusted mortality rates for males and females in the West Virginia coal mining counties and the income matched non-coal mining Appalachian counties with the 95% confidence intervals plotted for each time period

Table 1. All cancer mortality rates*

	Females						Males					
	Coal Mining			Non-Coal Mining			Coal Mining			Non-Coal Mining		
Time Period	Rate†	CI‡		Rate	CI		Rate	CI		Rate	CI	
1950–54	172.87	167.60,178.15		157.35	150.15,164.55	*	177.64	172.28,183.00		164.06	156.58,171.54	*
1955–59	162.98	158.16,167.80		153.59	146.82,160.37		201.06	195.59,206.53		168.96	161.65,176.28	*
1960–64	158.67	154.13,163.21		152.77	146.23,159.30		223.29	217.71,228.86		190.33	182.86,197.79	*
1965–69	163.08	158.63,167.53		150.29	144.00,156.57	*	238.70	233.01,244.38		201.20	193.60,208.80	*
1970–74	163.54	159.25,167.82		148.11	142.22,154.01	*	252.08	246.29,257.86		223.19	215.32,231.05	*
1975–79	160.78	156.73,164.83		149.88	144.21,155.54	*	265.65	259.84,271.46		244.89	236.99,252.80	*
1980–84	163.31	159.36,167.27		153.38	147.97,158.80	*	272.28	266.51,278.05		260.29	252.47,268.12	
1985–89	182.29	178.18,186.39		164.90	159.47,170.33	*	293.34	287.40,299.28		272.37	264.62,280.11	*
1990–94	191.98	187.85,196.11		171.04	165.74,176.35	*	304.36	298.48,310.23		292.53	284.81,300.26	
1995–99	192.56	188.49,196.63		176.25	171.01,181.49	*	298.42	292.73,304.10		283.31	275.99,290.64	*
2000–04	186.37	182.39,190.35		170.14	165.17,175.11	*	278.84	273.44,284.24		269.28	262.51,276.05	
2005–07	180.63	175.47,185.78		167.65	161.37,173.93	*	266.32	259.51,273.12		252.03	243.69,260.37	

* The table lists age-adjusted mortality rates for West-Virginia coal mining counties and the income matched non-coal mining counties. Statistically significant results are indicated by an * after the non-coal mining county 95% confidence interval.
† Rate is an age-adjusted mortality rate per 100,000 population.
‡ CI is a 95% confidence interval around the mortality rate.

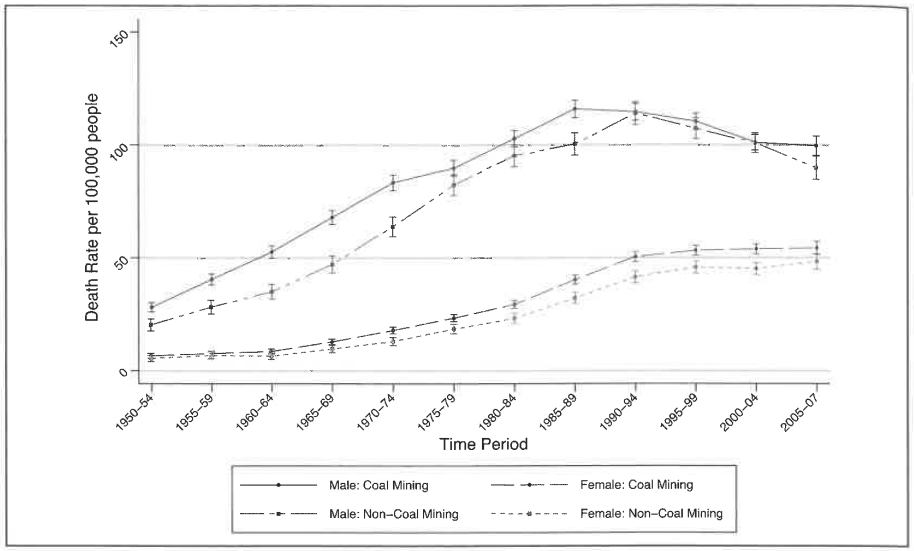

Figure 3. Respiratory cancer age-race adjusted mortality rates for males and females in the West Virginia coal mining counties and the income matched non-coal mining Appalachian counties with the 95% confidence intervals plotted for each time period

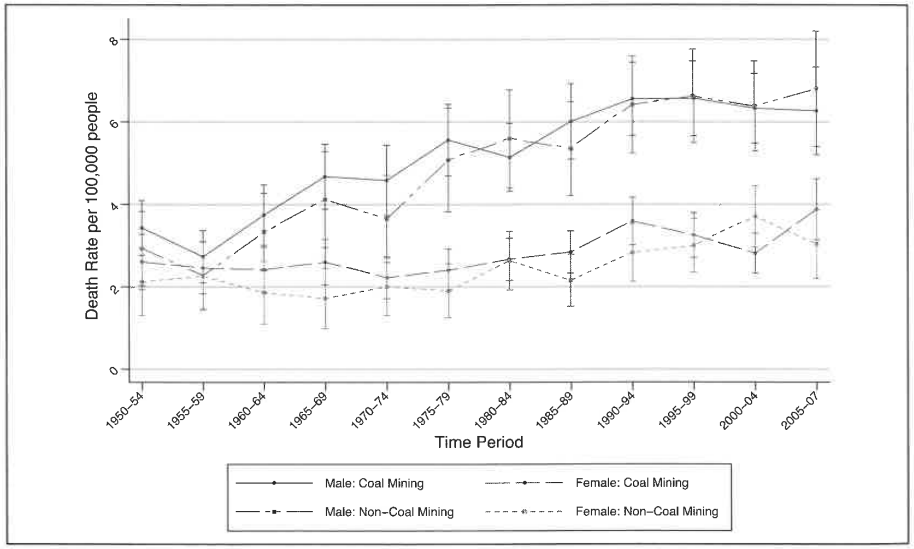

Figure 4. Kidney cancer age-race adjusted mortality rates for males and females in the West Virginia coal mining counties and the income matched non-coal mining Appalachian counties with the 95% confidence intervals plotted for each time period

Table 2. Kidney cancer mortality rates*

	Females				Males			
	Coal Mining		Non-Coal Mining		Coal Mining		Non-Coal Mining	
Time Period	Rate†	CI‡	Rate	CI	Rate	CI	Rate	CI
1950–54	2.60	1.93,3.28	2.12	1.30,2.94	3.43	2.77,4.10	2.93	2.03,3.83
1955–59	2.46	1.84,3.08	2.26	1.44,3.08	2.73	2.10,3.37	2.28	1.46,3.10
1960–64	2.42	1.88,2.96	1.86	1.10,2.62	3.74	3.01,4.48	3.33	2.39,4.27
1965–69	2.60	2.05,3.15	1.72	0.99,2.45	4.68	3.89,5.46	4.12	2.96,5.28
1970–74	2.22	1.72,2.73	2.00	1.31,2.70	4.59	3.73,5.44	3.65	2.60,4.71
1975–79	2.41	1.90,2.92	1.91	1.26,2.56	5.56	4.69,6.43	5.08	3.82,6.34
1980–84	2.67	2.17,3.17	2.64	1.94,3.33	5.14	4.32,5.97	5.59	4.41,6.78
1985–89	2.84	2.33,3.35	2.16	1.53,2.78	6.01	5.10,6.92	5.35	4.22,6.48
1990–94	3.59	3.01,4.17	2.83	2.13,3.53	6.55	5.67,7.44	6.42	5.24,7.59
1995–99	3.25	2.71,3.79	3.00	2.35,3.65	6.57	5.66,7.48	6.62	5.49,7.76
2000–04	2.81	2.33,3.30	3.71	2.97,4.45	6.33	5.48,7.18	6.38	5.29,7.47
2005–07	3.88	3.14,4.62	3.03	2.20,3.86	6.26	5.20,7.33	6.80	5.40,8.20

* The table lists age-adjusted mortality rates for West-Virginia coal mining counties and the income matched non-coal mining counties. Statistically significant results are indicated by an * after the non-coal mining county 95% confidence interval.
† Rate is an age-adjusted mortality rate per 100,000 population.
‡ CI is a 95% confidence interval around the mortality rate.

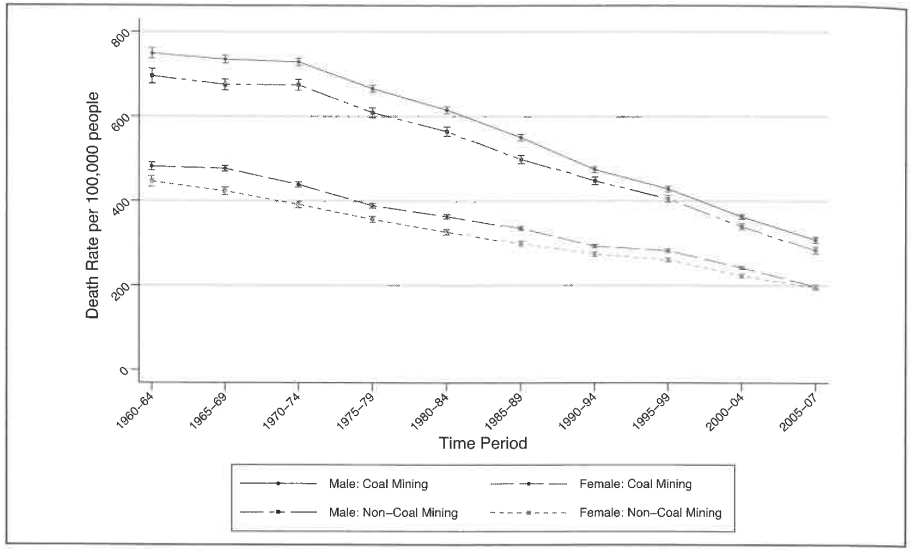

Figure 5. All heart disease age-race adjusted mortality rates for males and females in the West Virginia coal mining counties and the income matched non-coal mining Appalachian counties with the 95% confidence intervals plotted for each time period

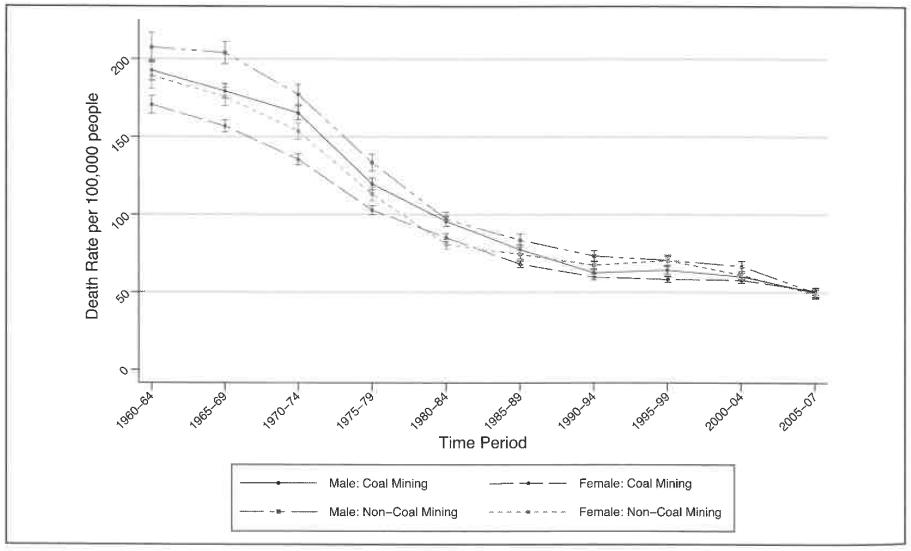

Figure 6. Stroke age-race adjusted mortality rates for males and females in the West Virginia coal mining counties and the income matched non-coal mining Appalachian counties with the 95% confidence intervals plotted for each time period

Table 3. Stroke mortality rates*

	Females						Males					
	Coal Mining			Non-Coal Mining			Coal Mining			Non- Coal Mining		
Time Period	Rate†	CI‡		Rate	CI		Rate	CI		Rate	CI	
1960–64	170.60	164.91,176.29		189.16	180.77,197.55	*	192.64	186.18,199.10		207.58	198.13,217.03	
1965–69	156.84	152.87,160.81		175.79	169.85,181.73	*	179.40	174.60,184.20		203.97	196.90,211.03	*
1970–74	135.51	132.01,139.01		153.62	148.32,158.92	*	165.30	160.83,169.78		177.20	170.75,183.65	*
1975–79	102.88	100.04,105.72		113.20	108.95,117.44	*	119.78	115.96,123.60		133.44	127.98,138.91	*
1980–84	85.30	82.80,87.80		80.92	77.62,84.21		95.75	92.46,99.04		97.13	92.51,101.74	
1985–89	68.02	65.91,70.13		74.26	71.28,77.23	*	77.54	74.57,80.52		83.46	79.37,87.55	
1990–94	59.81	57.86,61.75		67.24	64.51,69.98	*	62.58	60.02,65.14		73.16	69.60,76.72	*
1995–99	58.17	56.29,60.05		70.24	67.60,72.89	*	64.22	61.77,66.67		70.44	67.13,73.75	*
2000–04	57.70	55.88,59.52		61.03	58.59,63.48		60.12	57.80,62.43		66.62	63.43,69.81	*
2005–07	50.76	48.49,53.03		48.67	45.84,51.49		49.76	46.98,52.55		49.70	46.29,53.11	

* The table lists age-adjusted mortality rates for West-Virginia coal mining counties and the income matched non-coal mining counties. Statistically significant results are indicated by an * after the non-coal mining county 95% confidence interval.
† Rate is an age-adjusted mortality rate per 100,000 population.
‡ CI is a 95% confidence interval around the mortality rate.

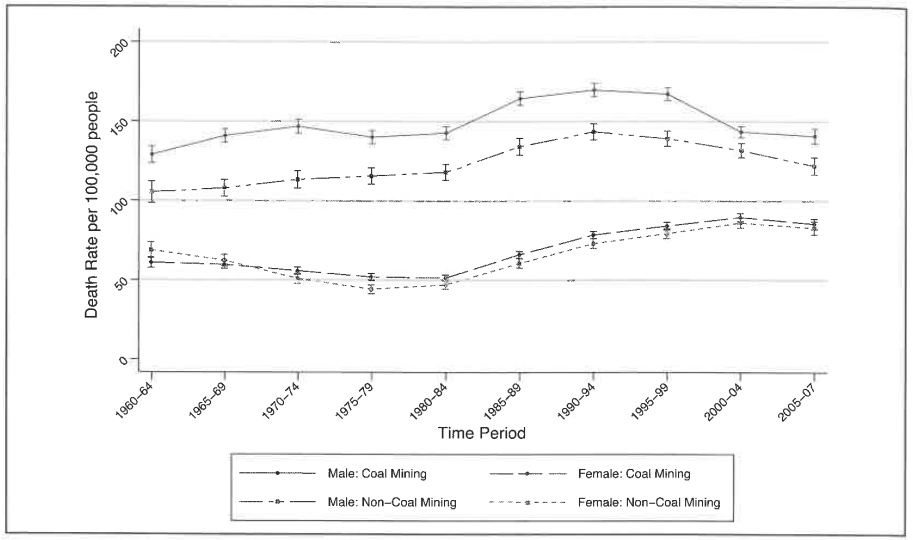

Figure 7. Non-malignant respiratory diseases age-race adjusted mortality rates for males and females in the West Virginia coal mining counties and the income matched non-coal mining Appalachian counties with the 95% confidence intervals plotted for each time period

mining compared to non-coal mining counties, similar to Hendryx and Zullig (Hendryx and Zullig 2009), which identified higher morbidity from heart disease among Appalachian coal mining and non-coal mining counties, compared to non-Appalachian, non-coal mining counties in the US.

However, higher mortality in coal mining counties was not consistently found across all causes examined, including kidney cancer and stroke, where non-coal mining counties had higher mortality. Hendryx et al. (Hendryx, et al. 2008, Hendryx 2009, Hendryx and Ahern 2009, Esch and Hendryx 2011) identified higher mortality risks for heart disease, respiratory disease, and kidney disease. The results found here do not entirely support those findings, although Hendryx did not use an Appalachian non-coal mining comparison for those analyses. While we did find elevated heart disease mortality risks among coal mining counties, we did not find excesses of kidney cancer. Our findings from NMRD are not at all consistent with the Hendryx (2009) findings.

The categories in which we found excesses are arguably heavily influenced by personal behaviors and risk factors, including heart disease (Schnohr, et al. 2002, Yong, et al. 2012), diabetes (Garber 2012) and lung cancer (Peto, et al. 2000). We were not able to control for personal risk factors in these analyses, including no control for confounding by smoking for causes of death highly affected by smoking such as heart disease and respiratory system cancer. Non-malignant respiratory disease had statistically significantly higher rates for males compared to females in all time periods and, among males, for coal mining counties compared to non-coal mining counties. Rather than being reflective of a pervasive effect of coal mines on the community, this pattern seems to reflect the effect of occupational lung diseases, such as pneumoconiosis, among males working in the coal mines (Suarthana et al. 2011).

Our findings also reflect the general trends in national mortality rates (Howlader et al., 2012). These include declines in total, heart disease, and stroke mortality. All cancer, respiratory, and

Table 4. Non-malignant respiratory disease mortality rates*

	Females					Males				
	Coal Mining		Non-Coal Mining			Coal Mining		Non- Coal Mining		
Time Period	Rate†	CI‡	Rate	CI		Rate	CI	Rate	CI	
1960–64	60.78	57.53,64.03	68.67	63.77,73.57		128.89	123.64,134.14	105.53	98.82,112.24	*
1965–69	59.59	57.08,62.10	62.22	58.50,65.94		140.91	136.62,145.20	107.69	102.48,112.91	*
1970–74	55.68	53.35,58.00	50.87	47.68,54.05		146.77	142.41,151.12	113.16	107.74,118.58	*
1975–79	51.84	49.72,53.96	44.18	41.45,46.90	*	140.06	135.91,144.22	115.38	110.18,120.57	*
1980–84	51.29	49.29,53.30	46.99	44.32,49.67		142.78	138.73,146.84	117.91	112.84,122.97	*
1985–89	66.00	63.81,68.19	60.51	57.60,63.42	*	164.56	160.33,168.78	134.04	128.76,139.32	*
1990–94	78.37	76.08,80.66	72.96	69.96,75.97	*	169.87	165.72,174.02	143.34	138.28,148.40	*
1995–99	84.00	81.62,86.38	79.20	76.14,82.26		167.23	163.23,171.23	139.08	134.31,143.85	*
2000–04	89.52	87.04,92.00	86.00	82.81,89.19		143.42	139.83,147.01	131.78	127.33,136.22	*
2005–07	85.35	82.12,88.59	82.81	78.73,86.89		140.88	136.21,145.54	121.90	116.48,127.33	*

* The table lists age-adjusted mortality rates for West-Virginia coal mining counties and the income matched non-coal mining counties. Statistically significant results are indicated by an * after the non-coal mining county 95% confidence interval.
† Rate is an age-adjusted mortality rate per 100,000 population.
‡ CI is a 95% confidence interval around the mortality rate.

Table 5. Demographic data for coal mining and non-coal mining counties

	Coal Mining Counties		Non-Coal Mining Counties	
Demographic Quantity	average	range	average	range
Median income ($)	32,853	20,496–43,628	33,020	22,261–44,302
Non-white residents (%)	4.5	1.0–15.9	3.7	1.2–11.1
Individuals over 65yrs (%)	16.8	10.2–20.9	17.4	11.1–22.5

Source: US Census 2010.

kidney cancer mortality rates have not seen the same declines and have increased or remained stable over time (Howlader et al., 2012). The patterns found here in our comparison of WV coal mining counties with Appalachian non-coal mining counties are consistent with changes in rates in the US over time.

Thirty-one WV coal mining and their non-coal mining county median family income matches were used in these analyses, although the results were aggregated by mining status not by matched pair. We chose to use income when determining a match leading to some coal-mining counties being matched to non-coal mining counties several counties away, including in neighboring states. While not used in matching, other demographic factors were similar. As shown in our companion paper (Talbott, et al., submitted) and highlighted in Table 5, the average proportion of non-white residents in coal mining and non-coal mining counties is similar (4.5% (range 1.0–15.9%)and 3.7% (range 1.2–11.1%), respectively). Overall the proportion of individuals over 65 is also very similar in the coal and non-coal mining counties (16.8% (range 10.2–20.9%) and 17.4% (range 11.7–22.5%), respectively). A total of 16.2% of West Virginians are aged 65 and older which is considerably higher than the national average level of 13.3% (US Census, 2010). However, differences in potential mortality confounding factors, such as education, personal risk factors, access to health care, and health beliefs, could be affecting mortality patterns (Lengerich, et al. 2004, Lengerich, et al. 2006).

This study had some limitations. Because we used one-to-one matching for the counties, slight differences in demographic factors could disproportionately affect the mortality rates, although the counties were aggregated here, lessening that potential. We defined coal mining as being present in 1994 based on EIA data, similar to what was done in the Hendryx analysis (Hendryx 2009); this may not reflect historical mining patterns or subsequent mine closings in the counties assessed. Further analyses using more complete historical data, including the amount of coal mined and the type of mining (surface or underground) should be conducted. For some cause of death categories, including kidney cancer, the small numbers of death led to imprecise estimates with larger confidence intervals, although mortality patterns could still be detected. In such cases, we placed less emphasis on the estimate and its confidence interval and more on the patterns found in the rates.

The results of these analyses indicate that, without control for some potential confounding factors, total and cause-specific mortality is only elevated in WV coal-mining counties relative to Appalachian non-coal mining counties for certain causes of death. Additional studies of Appalachian mortality are required to understand the complex interactions of factors in that area. These studies should include full consideration to the many confounding factors associated with mortality in these areas, and have a full understanding of the environmental conditions in Appalachia, which include not only the coal mining industry but also the chemical industry.

ACKOWLEDGMENT

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