Comparison of Mortality Disparities in Central Appalachian Coal- and Non–Coal-Mining Counties

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Objective: Determine whether select cause of death mortality disparities in four Appalachian regions is associated with coal mining or other factors. **Methods:** We calculated direct age-adjusted mortality rates and associated 95% confidence intervals by sex and study group for each cause of death over 5-year time periods from 1960 to 2009 and compared mean demographic and socioeconomic values between study groups via two-sample *t* tests. **Results:** Compared with non–coal-mining areas, we found higher rates of poverty in West Virginia and Virginia (VA) coal counties. All-cause mortality rates for males and females were higher in coal counties across all time periods. Virginia coal counties had statistically significant excesses for many causes of death. **Conclusions:** We found elevated mortality and poverty rates in coal-mining compared with non–coal-mining areas of West Virginia and VA. Future research should examine these findings in more detail at the individual level.

Recent studies have continued to document that, compared with other US regions, adverse health outcomes occur at higher rates in Appalachia, which includes all of West Virginia (WV) and parts of other states.[1–5] Nevertheless, conflicting evidence has been found regarding whether these disparities are due in part to the environmental effects of coal mining in Appalachia or to other social, economic, or health factors.[1–3,6–8] Our earlier examination of mortality patterns in WV coal-mining counties, compared with Appalachian non–coal-mining counties with comparable incomes, found statistically significantly higher total mortality and higher mortality rates for some specific causes of death in coal-mining compared with non–coal-mining counties.[9] Nevertheless, the findings for total mortality did not seem to be associated with coal production.[10]

In this study, the geographic area of interest was expanded to include the Appalachian coal-mining and non–coal-mining counties of southwestern Virginia (VA). Appalachian VA, which includes only 25 of VA's 131 state counties and cities, is geographically and demographically more similar to Appalachian counties in neighboring states than to the rest of VA.[11] To further evaluate whether coal mining is associated with mortality in Appalachia, we compared mortality patterns from 1960 to 2009 in coal-mining and non–coal-mining counties in WV and Appalachian VA.

METHODS

We conducted descriptive and statistical analyses of total and select cause-specific mortality rates in WV and VA coal-mining counties and compared those with WV and VA non–coal-mining counties.

Details regarding the methodology of the WV comparison have been presented elsewhere.[9,10] In brief, we identified WV coal-mining and Appalachian non–coal-mining counties using data from the Appalachian Regional Commission (ARC)[12] and the Energy Information Agency.[13] In the previous study, we matched coal-mining to non–coal-mining counties based on median income (±5%), occasionally matching counties from neighboring states using US Census Bureau information.[14] We used the Mortality and Population Data System (MPDS)[15] 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 deaths in the United States. It has codes for cancer causes for deaths between 1950 and 2007 and codes for noncancer causes, including total mortality, between 1960 and 2007.

Appalachian VA counties were identified from ARC data, and coal production data were captured from the Energy Information Agency records for the same 1983 to 2009 time period. Because VA has a limited number of counties defined as "Appalachian," we used Appalachian VA noncoal producing counties as comparison without attempting to match on median income. The counties in Lenowisco and Cumberland Plateau Health Districts (Southwest) were considered coal-mining, and counties directly to the east in Mount Rogers and Western Piedmont Health Districts were the comparison counties.

Counts of death in the coal and non–coal-mining counties of southern VA were tabulated from individual mortality records obtained from the Virginia Department of Health (VDH). These records contain the underlying cause of death, coded to the ICD revision in effect at time of death, for all deaths in the study counties in VA between 1960 and 2009. We validated the VDH counts of death using the National Center for Health Statistics counts of death via MPDS.[15] It was determined that all VDH deaths in 1968 were coded using the ICD, seventh revision, instead of the nationally prevailing ICD, eighth revision. As such the ICD, seventh revision, was used to categorize 1968 VDH death records instead of the eighth revision.

The specific causes of death evaluated were total mortality (ICD, 10th revision, codes A00–Y89), respiratory system cancer (RSC) (ICD, 10th revision, codes C30–C39), nonmalignant respiratory disease (NMRD) (ICD, 10th revision, codes J00–J99), and all external causes (ICD, 10th revision, codes V01–Y89). We used the mid-year US Census annual population estimates for the county populations at risk, which were obtained from MPDS,[15] to calculate direct age-adjusted mortality rates.

We calculated direct age-adjusted mortality rates by sex and study group for each specific cause of death over 5-year time periods (1960 to 2009). Age adjustment was done using a 12 category age distribution (0 to 4, 5 to 9, 10 to 14, 15 to 19, 20 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, 75 to 84, older than 85 years) and weights from the 2000 US Standard Population. We also calculated the associated 95% confidence intervals (CI). These mortality rates and CIs were calculated using the "epitools" packages in R.[16] This package produces direct age-adjusted rates with gamma-based CI.[17]

We performed a graphical analysis comparing the age-adjusted mortality rates between WV coal-mining counties, area non–coal-mining comparison counties, VA coal-mining counties,

and VA non–coal-mining comparison counties for males and females. Graphs were created for each cause of death of interest and included both the age-adjusted mortality rate and associated 95% CIs at each 5-year time period. Age-adjusted mortality rates were considered statistically significantly different if the 95% CIs were not overlapping.

We also collected information on selected county-level factors to characterize the demographic and socioeconomic profile of the four regions studied, including percentage of nonwhite[18]; percentage of population below poverty line; percentage of people older than 25 years of age who graduated high school; smoking prevalence for current smokers older than 18 years of age,[19] obesity rate[20]; and percentage of the population older than 65 years of age.[14] We compared the mean values for each characteristic between WV and VA coal mining counties; WV coal and comparison counties; VA coal and comparison counties; and WV and VA comparison counties. For each comparison, we tested for statistically significant differences between the mean values at an alpha level of 0.05 using two-sample *t* tests.

RESULTS

Figure 1 identifies the WV and VA coal and comparison non–coal-mining counties included in the analyses. As shown, coal mining in WV occurs throughout the state with income-matched counties located in WV, North Carolina, Tennessee, and Kentucky, whereas the VA coal-mining and non–coal-mining counties were concentrated in southwest VA. Table 1 shows the mean and range by study area for total cumulative county coal production and select population characteristics. Virginia coal-mining counties had slightly higher cumulative coal production than WV coal-mining counties.

The coal-producing counties had higher poverty rates and higher smoking rates than the comparison counties; however, the only statistically significant differences found were between the VA coal and comparison counties ($P = 0.0019$ and $P = 0.0144$, respectively). West Virginia counties tended to have higher obesity rates compared with VA counties, with the following comparisons being statistically significantly different: WV coal versus VA coal ($P < 0.0001$), WV comparison counties versus VA comparison counties ($P = 0.0005$), and WV coal versus WV comparison counties ($P = 0.0005$). Nevertheless, the percentage of the population older than 65 years of age was similar among all groups. The percentage of high school graduates was slightly higher in WV counties than in VA counties with significant differences between WV coal and VA coal ($P = 0.0023$) and VA coal versus VA comparison counties ($P = 0.0183$).

All-cause mortality rates for males (Fig. 2) and females (Fig. 3) generally declined over time with the exception of an increase in mortality in VA females in coal counties in the 1990s. All-cause mortality rates for males and females were consistently statistically significantly higher in coal-mining counties compared with non–coal-mining counties across all time periods. Virginia coal mortality rates were higher than WV mortality rates with many excesses being statistically significant. Nevertheless, for the most recent time period (2005 to 2009), the rates for WV and VA males in coal counties were not statistically significantly different. The highest rates among females were in VA coal counties from 1995 to 2009, which were statistically significantly higher than all other female study groups.

Figures 4 and 5 show the rates for all external causes of mortality decreased over time until the 1990s for both males and
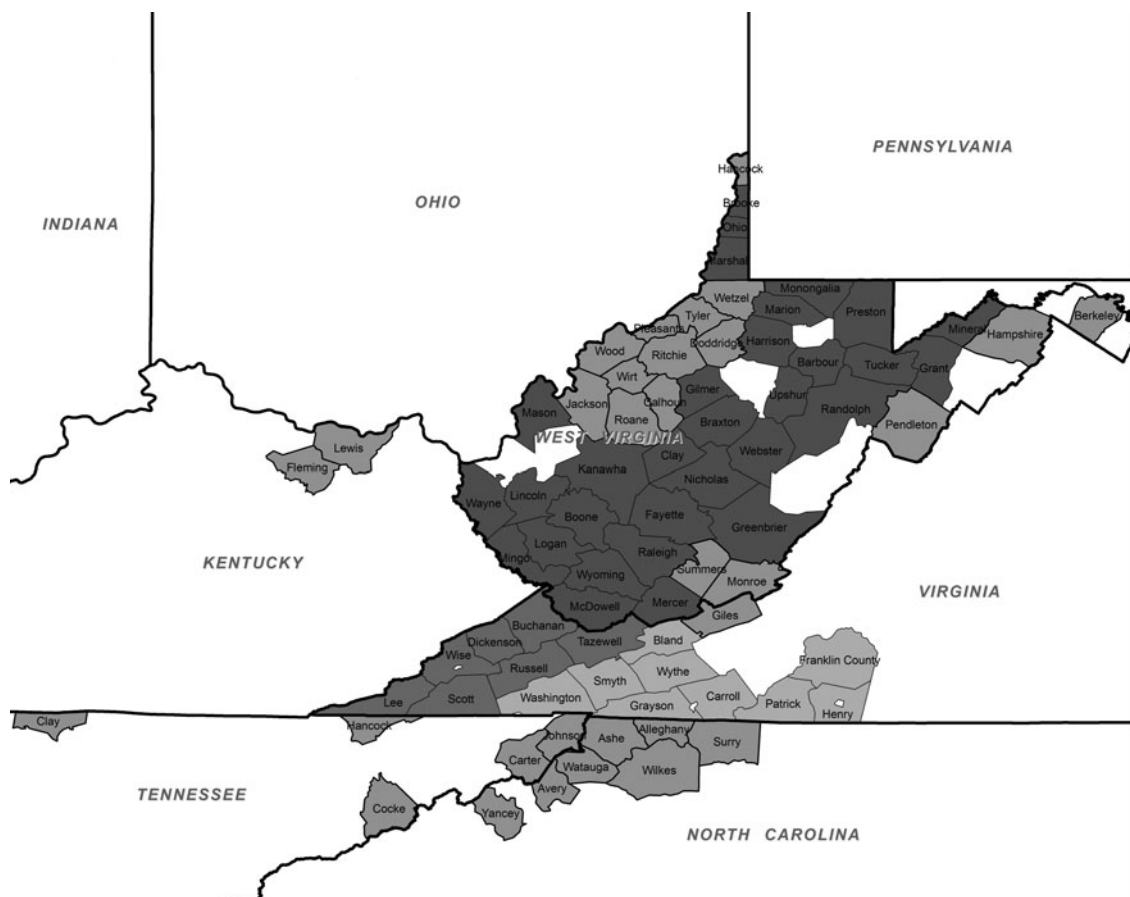

FIGURE 1. West Virginia and Virginia coal-producing and comparison counties in the study areas

TABLE 1. Comparison of Select Characteristics for Study Areas

	Coal Production		% Nonwhite		% Poverty		% HS Graduates		% Smoking		% Obese		% 65+	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
WV coal	1.31E + 08	7.43E + 05–7.17E + 08	3.7	1–13	21.1	12–38	71.2*	50–84	33.9	27–43	29.0*†	25–36	15.5	11–19
WV comparison	NA	NA	3.2	0.6–10	17.7	10–29	70.1	56–83	32.3	25–41	26.8†‡	20–31	15.5	11–20
VA coal	1.37E + 08	7.46E + 05–3.60E + 08	2.6	1–4	19.6§	16–24	61.4*	53–68	34.7	31–39	24.7*	23–26	14.6	12–18
VA comparison	NA	NA	7.8	2–26	12.9§‖	11–14‖	67.1§‖	62–72‖	31.3§	27–34	23.6‡	22–26	15.7	14–17

*Difference between WV coal and VA coal statistically significant at $P < 0.05$.

†Difference between WV coal and WV comparison statistically significant at $P < 0.05$.

‡Difference between WV comparison and VA comparison statistically significant at $P < 0.05$.

§Difference between VA coal and VA comparison statistically significant at $P < 0.05$.

‖Data for Franklin County was not available (on arc.gov) for these two characteristics (% Poverty and % HS Grads).

HS, high school; NA, not available; WV, West Virginia; VA, Virginia.

Data sources: Coal Production: EIA (1983–2009); % Nonwhite: Census (2000); % Poverty: arc.gov (2000); % HS Graduates: arc.gov (2000); % Smoking: National Cancer Institute (2003); % Obese: CDC (2004); % 65+: Census (2000).
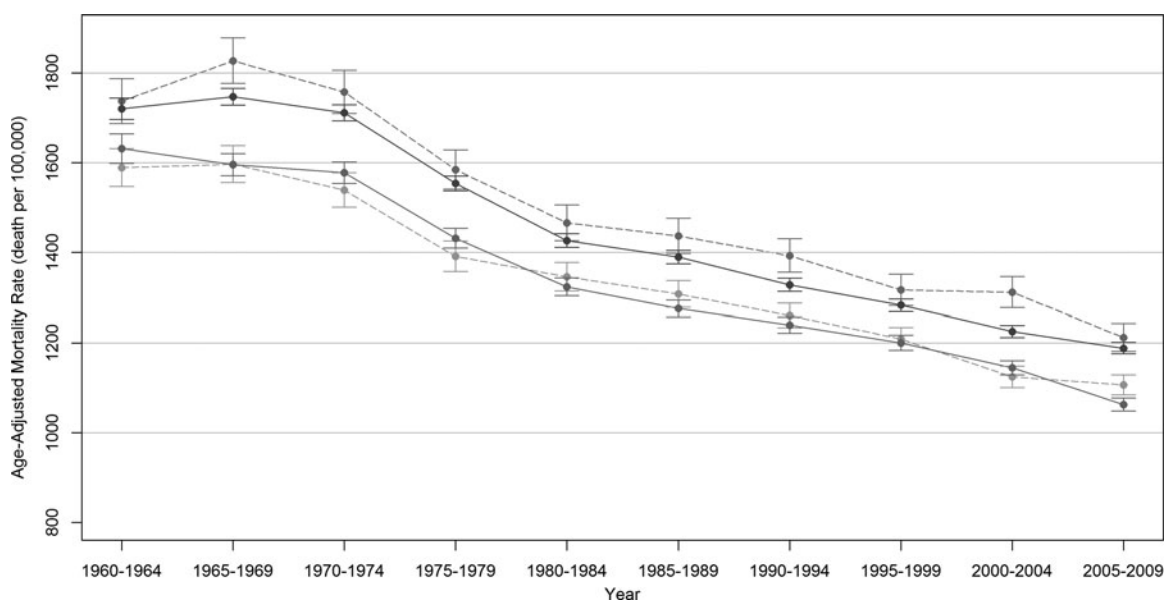
FIGURE 2. All-cause age-adjusted mortality rates: males.

females in all study groups after which the rates began increasing. No statistically significant differences between the WV coal and non–coal-mining counties were observed over time. Male rates of all external causes of mortality in VA were higher than rates in the other study groups, and many of these differences were statistically significant. The rates of all external causes of death for VA females in coal counties went from the lowest point of approximately 35 deaths per 100,000 to almost double that rate, more than 60 deaths per 100,000, in the last 20 years examined. These rates were statistically significantly higher than in the other study groups starting in the mid-1990s.

Respiratory system cancer mortality rates are depicted in Figs. 6 (males) and 7 (females) and reflect male rates that peaked in the 1990s and then declined and female RSC mortality rates that increased over time. The male mortality rates in the WV coal group were statistically significantly higher than those of the WV non-coal group until 1990 where CIs began to overlap. The VA male coal group mortality rates were statistically significantly higher than

those of the VA male comparison group rates except from 1970 to 1984. The female RSC mortality rates in the WV coal group were the highest examined, although they were not statistically significantly different from the female VA coal group; both coal groups have statistically significantly higher rates than their respective comparison groups beginning in the early 1980s.

As shown in Figs. 8 and 9, the NMRD mortality rates were highest in the VA coal group for both males and females. Similar to RSC mortality rates, NMRD male mortality rates for WV and VA coal groups were statistically significantly higher than their respective comparison groups throughout the entire time period. Although male NMRD rates remained relatively constant, female NMRD mortality rates have increased since the 1980s. The female mortality rates for the WV coal group were not statistically significantly different than the WV comparison group except for the interval from 1990 to 1994. Nevertheless, the female NMRD mortality rates for the VA coal group were statistically significantly higher than the VA comparison group except from 1975 to 1989.
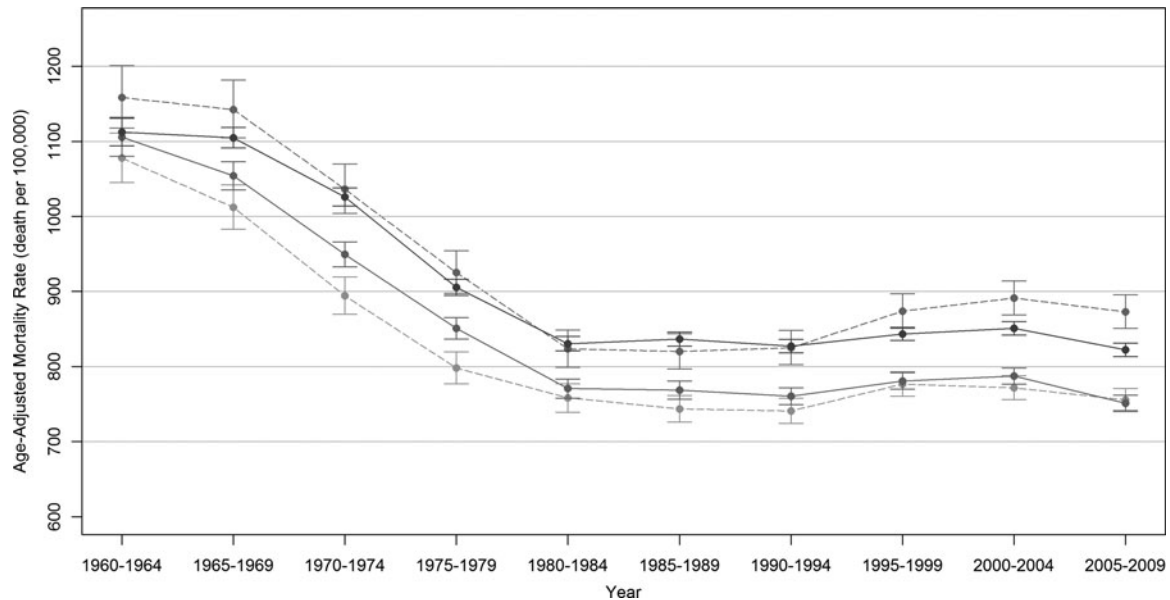
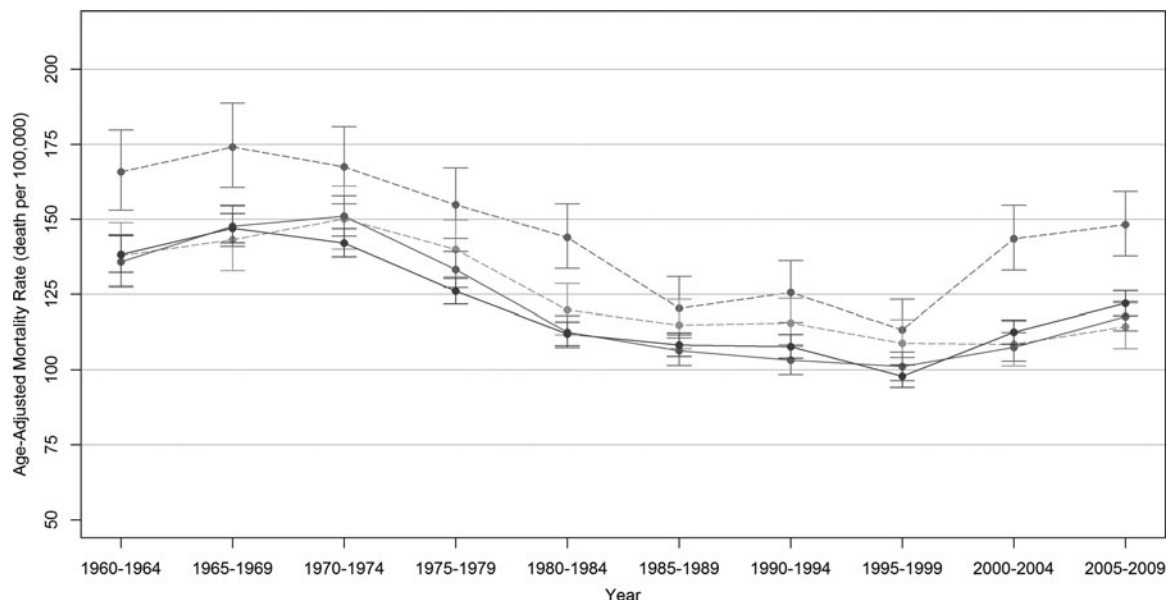**FIGURE 3.** All-cause age-adjusted mortality rates: females.

FIGURE 4. All external causes age-adjusted mortality rates: males.

DISCUSSION

This study is the first to compare mortality rates in WV and VA coal-mining and Appalachian non–coal-mining counties over a 50-year period. Other mortality studies in Appalachia have been restricted to examining much shorter periods of mortality[1–3,7,21–25] or did not include VA counties,[9,10] whereas this study examined mortality patterns over 50 years (noncancer causes of death) or 60 years (cancer causes of death) in both WV and VA. The findings of higher age-adjusted mortality rates for many causes of death in VA coal-mining counties compared with VA non–coal-mining counties are consistent with our previous work in WV.[9] Adjustment for socioeconomic and personal risk factors attenuated these findings in WV.[10] Similar analyses are underway for the VA region. These adjustments may provide evidence that mortality excesses in Appalachian coal-mining regions are more influenced by socioeconomic factors in the area other than coal production per se.

The findings of elevated all-cause mortality in coal-mining counties are similar to results found in coal miners. In a study of British coal miners by Miller et al,[26] while the authors found no statistically significant all-cause SMR of 100.9 for the total time period (1950 to 2009), they noted that there was "evidence of healthy worker effect early in the follow-up." Indeed, they found that the all-cause SMR for the most recent time period examined (1990 to 2005) was statistically significantly increased (SMR = 109.6; 95% CI, 106.5 to 112.8). Similarly, in their study of US underground coal miners, Attfield and Kuempel[27] indicated that, while all-cause mortality SMRs were near 100 and not statistically significant, "evidence of a healthy worker survival effect (which could obscure the true exposure–response relationship) was observed."

Although the coal-mining areas of WV and VA have higher mortality rates for conditions reported relative to the comparison
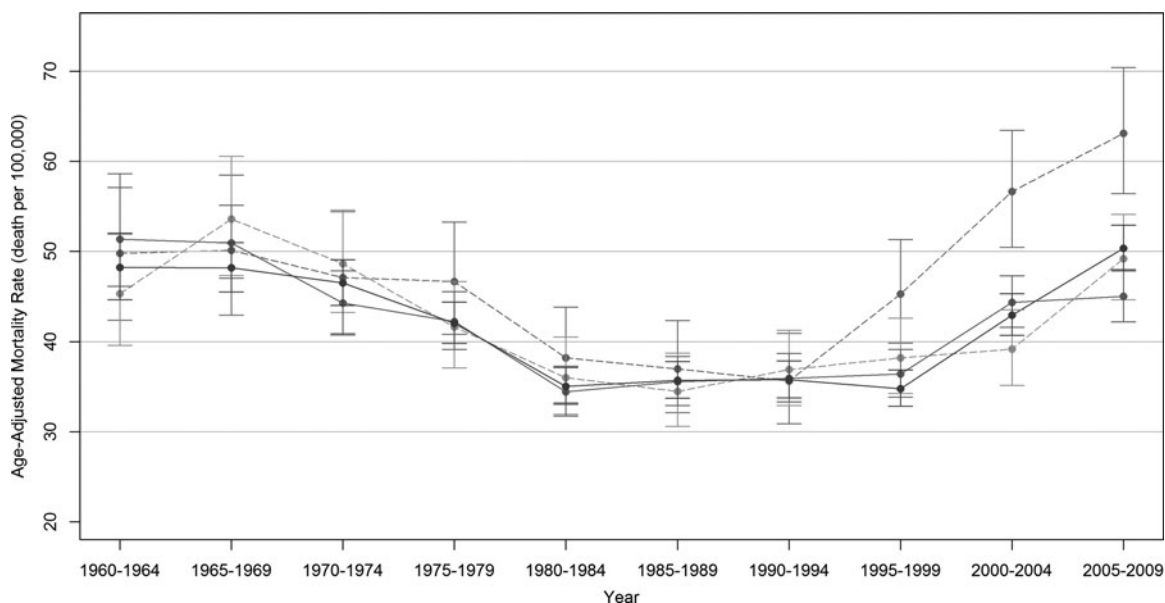
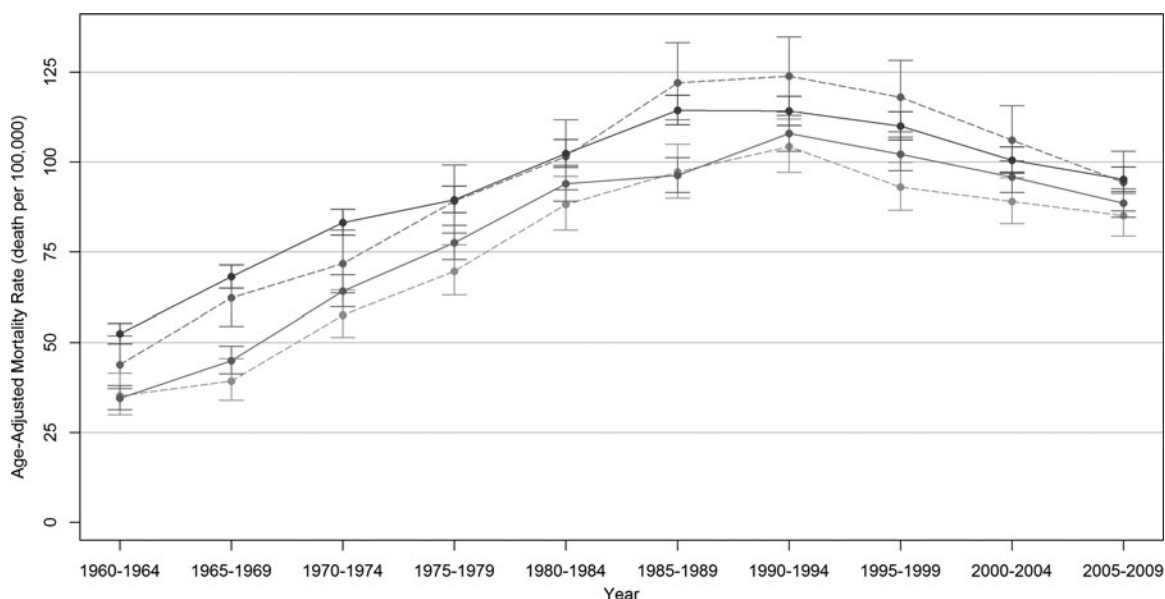**FIGURE 5.** All external causes age-adjusted mortality rates: females.

FIGURE 6. Respiratory system cancer age-adjusted mortality rates: males.

counties, the most striking finding in this study was the poorer mortality outcomes among coal-mining counties of VA for many of the causes of death examined including all-cause mortality. In addition, trends for female mortality rates, particularly in VA coal areas, were also found to be increasing at greater rates than in males in more recent years, especially for age-adjusted mortality due to all external causes, RSC, and NMRD. Many of these disparities were statistically significantly different compared with the other study areas. The WV and VA coal counties examined had similar coal production over the study period, indicating that coal production should not be considered the sole factor influencing these mortality disparities.

As shown in Table 1, we found higher rates of poverty in WV and VA coal-mining counties than in the comparison counties; these socioeconomic differences may be adversely affecting mortality. Research by the ARC indicates that mean household income in Appalachian VA decreased 8.5% from 1999 to 2005–2009 compared with a 3.5% decrease in WV over the same time periods.[28] These decreases in income are consistent with indications that many of the coal-mining counties in central Appalachia are considered "distressed."[28] In the counties studied, these findings provide additional evidence that socioeconomic conditions are primary factors in poor health outcomes.[28]

The examination of external causes of death was intended primarily as a "control" cause of death category and was not expected to be related to coal production because this category is composed of suicides, homicides, and accidents (both motor vehicle related and other). The findings of statistically significantly higher mortality in VA coal-mining counties may indicate more risk-taking behavior or less access to health care or mental health services in these health
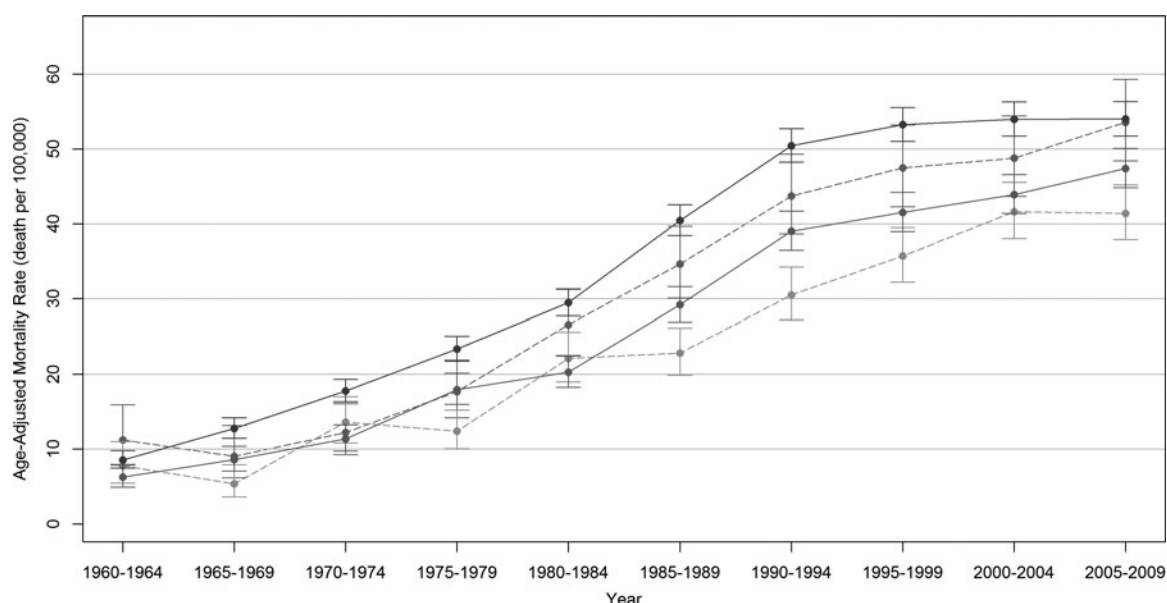
FIGURE 7. Respiratory system cancer age-adjusted mortality rates: females.
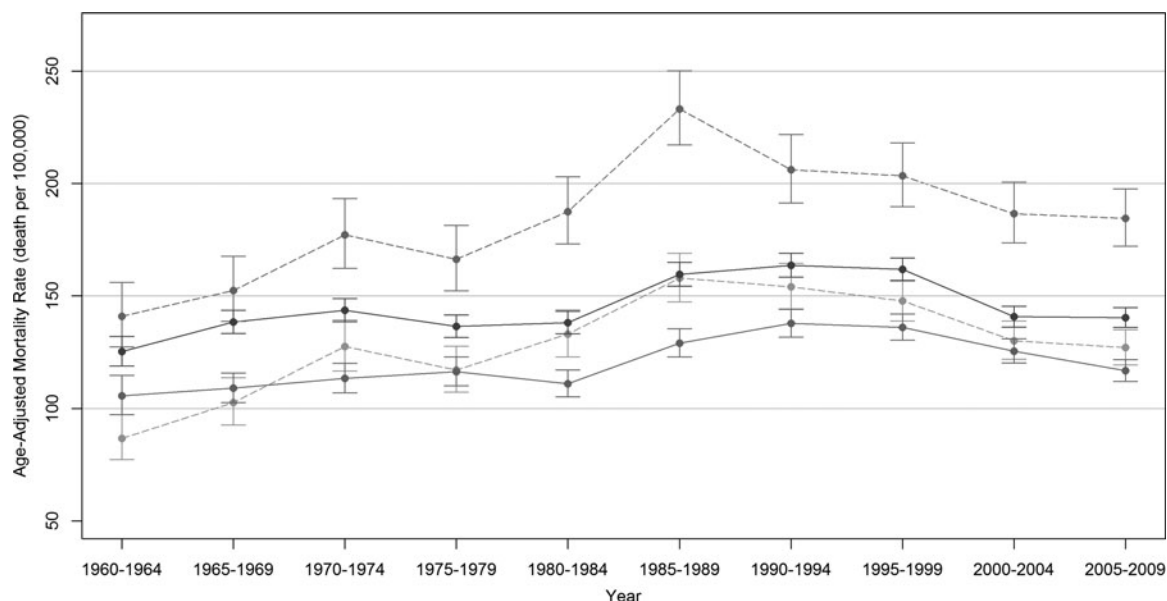

FIGURE 8. Nonmalignant respiratory disease age-adjusted mortality rates: males.

districts. The coal counties are located in the VA health districts of Lenowisco and Cumberland Plateau, which are known to experience greater health disparities than average for the state.[29]

Respiratory system cancer mortality rates were higher in coal-mining counties of both WV and VA, although the differences were primarily among females, especially in the more recent time periods examined. Although there were no statistically significant differences in smoking rates between coal and comparison groups for males, there were lower smoking rates in women in VA comparison counties compared with VA coal counties that approached statistical significance (Table 1). Smoking rates among women have decreased less than those among men from 1996 to 2012 according to a recent publication.[30]

Nonmalignant respiratory disease was associated with higher rates of mortality among VA males and females in coal-mining coun-

ties compared with all other counties. Nonmalignant respiratory disease is associated with smoking,[31] and in this study higher smoking rates were reported among females in VA coal-mining counties, but not males, compared with VA non–coal-mining counties. Nonmalignant respiratory disease also has environmental and occupational causes.[32] Coal production was similar between WV and VA coal groups for the time period examined. In 2014, it was reported that 2% of workers in Appalachian VA were employed in coal mining and other forms of mining compared with 4.4% in WV.[33] Thus, the increases seen in women, who have less direct exposure than men to coal as an occupational factor, and the lower coal production and/or mining in VA make coal an unlikely cause for the higher rates of NMRD.

This study has several strengths. This is the first study to examine mortality in two Appalachian coal mining areas over a 50-year
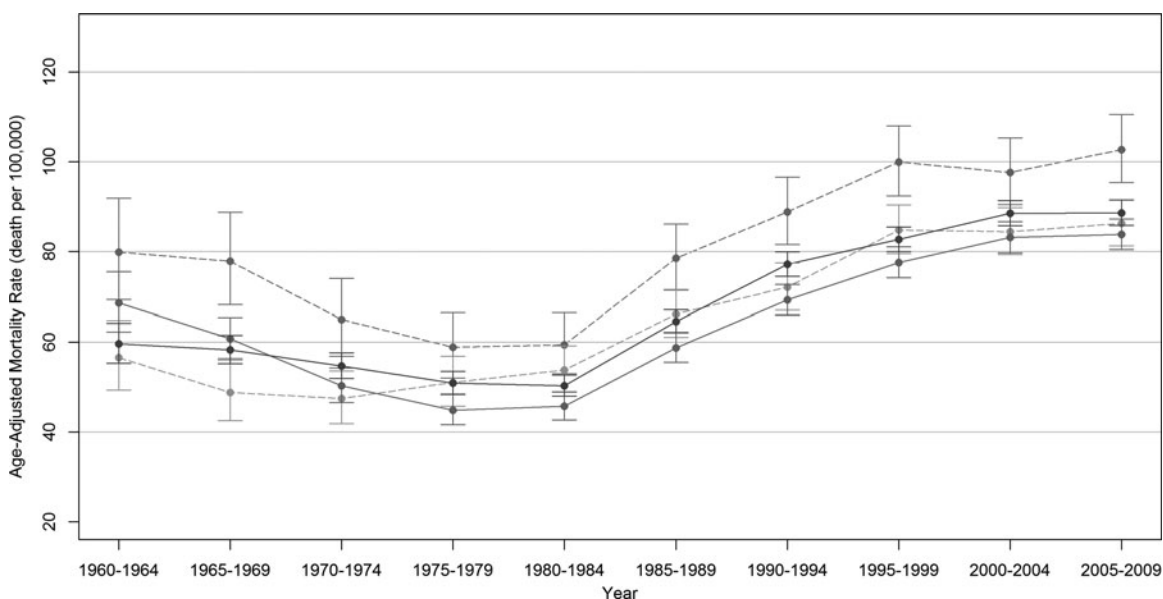
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FIGURE 9. Nonmalignant respiratory disease age-adjusted mortality rates: females.

time period. This allows a better understanding of changes in mortality over time. The use of comparison counties within Appalachia provided control for some of the geographic and socioeconomic conditions unique to that area. Nevertheless, as shown in Table 1, within-area differences existed, especially with percentage living below the poverty level, educational attainment, and percentage of the population considered obese. The study limitations include the use of only group-level data for all covariates and coal production, thus prohibiting the ability to evaluate a causal effect between mortality and cumulative coal exposure. Although these findings are intriguing, they should be confirmed using individual-level data to evaluate whether living in areas of high coal production is associated with higher mortality. Analyses based on group-level data only may be biased because of the ecological fallacy; this bias may even reverse effect estimates.[34,35] Also, no formal adjustment for multiple comparisons was performed so some statistically significant findings may simply be due to chance.

CONCLUSIONS

The study results provide additional evidence that mortality rates for many chronic health conditions continue to be higher in coal producing counties in Appalachia. This region has an especially complex relationship between health and environmental, personal, and socioeconomic risk factors. More research is needed, including better control for individual-level risk factors, to allow for cause–effect relationships to be identified.

ACKNOWLEDGMENTS

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