
Volume 49, Issue 5, November 2009
ELSEVIER
PM
Preventive Medicine
This Month in
Preventive Medicine
Time Machines: A Promising Attempt to Reduce TV Watching
Heart Disease and Coal Mining
Higher CHD and heart attack morbidity in Appalachia
Diabetes and Hearing Impairment
30-year change in the U.S.
Body Weight/Fatness and Smoking
Meta-analysis of 10 European countries in the EPIC Study
Body Weight and Alcohol/Blood Pressure/Serum Lipids
Influence on associations among working women in Japan
Body Weight and Depression/Smoking
Associations among northwest U.S. female health plan enrollees
Weight Loss
Maintenance-Tailored vs. Standard Behavior Therapy for treating obesity
Cost-effectiveness of a behavioral intervention for low-income women
Correlates with metabolic syndrome in NHANES
Physical Activity
Association with insulin resistance among adults in Iran
Levels among children/youth in Nova Scotia
Levels during school recess among Hungarian children
Children's TV Watching
Pilot study of electronic time monitors
Lifestyle and Health
Self-reported health in a general population in Denmark
5-year changes in self-reported mental/ physical health
Adolescent Substance Abuse Prevention
Computer-delivered, parent-involvement intervention for adolescent girls
Colorectal Cancer Screening
Are gender differences among veterans due to differences in self-reporting?
Skin Cancer Prevention
Economic evaluation of the SunSmart program in Australia
Book Review
Molecular Epidemiology of Chronic Diseases
Available online at
ScienceDirect
www.sciencedirect.com

Preventive Medicine 49 (2009) 355–359

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Higher coronary heart disease and heart attack morbidity in Appalachian coal mining regions

Michael Hendryx *, Keith J. Zullig

Department of Community Medicine, West Virginia University, One Medical Center Drive, PO Box 9190, Morgantown, WV 26506, USA

ARTICLE INFO

Available online 15 September 2009

Keywords:
Cardiovascular health
Mining
Coal
Appalachian region
Environmental health

ABSTRACT

Background. This study analyzes the U.S. 2006 Behavioral Risk Factor Surveillance System survey data (N = 235,783) to test whether self-reported cardiovascular disease rates are higher in Appalachian coal mining counties compared to other counties after control for other risks.

Methods. Dependent variables include self-reported measures of ever (1) being diagnosed with cardiovascular disease (CVD) or with a specific form of CVD including (2) stroke, (3) heart attack, or (4) angina or coronary heart disease (CHD). Independent variables included coal mining, smoking, BMI, drinking, physician supply, diabetes co-morbidity, age, race/ethnicity, education, income, and others. SUDAAN Multilog models were estimated, and odds ratios tested for coal mining effects.

Results. After control for covariates, people in Appalachian coal mining areas reported significantly higher risk of CVD (OR = 1.22, 95% CI = 1.14–1.30), angina or CHD (OR = 1.29, 95% CI = 1.19–1.39) and heart attack (OR = 1.19, 95% CI = 1.10–1.30). Effects were present for both men and women.

Conclusions. Cardiovascular diseases have been linked to both air and water contamination in ways consistent with toxicants found in coal and coal processing. Future research is indicated to assess air and water quality in coal mining communities in Appalachia, with corresponding environmental programs and standards established as indicated.

Recent studies have documented poor population health outcomes in coal mining areas of Appalachia compared to other parts of the region or the nation (Hendryx, 2008, 2009; Hendryx and Ahern, 2008; Hendryx et al., 2008). These findings include higher chronic cardiovascular disease (CVD) mortality rates (Hendryx, 2009) and higher rates of self-reported CVD (Hendryx and Ahern, 2008).

The risk for CVD is influenced by environmental, behavioral, genetic, demographic, and health services variables. (Galimanis et al., 2009; Marmot and Wilkinson, 2005). Risk behaviors, in turn, are related to lower socioeconomic status (SES); low SES persons are more likely to smoke, consume poor quality diets, and engage in sedentary lifestyles (Darmon and Drewnowski, 2008; Harwood et al., 2007; Marmot and Wilkinson, 2005; Woolf et al., 2006). Coal mining areas are characterized by lower SES relative to non-mining areas (Halverson and Bischak, 2007; Hendryx, 2008; Wood, 2005), suggestive of higher CVD risk.

Environmental agents that contribute to CVD include arsenic, cadmium and other metals, non-specific particulate matter (PM), and polycyclic aromatic hydrocarbons (PAHs) (Bhatnagar, 2006; Mastin, 2005; Miller et al., 2007). All of these agents are present in coal or introduced into local ambient environments via activities of coal extraction and processing (Ghose, 2007; Kolker et al., 2006; McAuley and Kozar, 2006; WVGES, 2007).

Most previous research on population health in coal mining areas has employed county-level mortality data rather than individual-level data. An exception was a study of self-reported chronic illness in relation to coal mining (Hendryx and Ahern, 2008); this study was limited to a non-standard assessment instrument with limited individual-level covariates in one state. The current study uses national Behavioral Risk Factor Surveillance System (BRFSS) data to assess CVD risk in coal mining areas before and after control for individual-level covariates including smoking, obesity, co-morbid diabetes, alcohol consumption and others. We test the hypothesis that CVD rates will be significantly elevated for residents of Appalachian coal mining counties after controlling for covariates, suggestive of an environmental impact. We also hypothesize that effects will be present for men and women, an indication that effects represent more than direct occupational exposure among male coal miners.

Methods

Design

The study is a retrospective analysis of 2006 BRFSS (CDC, 2007a) data on CVD in relation to individual and county-level risks, with a focus on Appalachian coal mining. The BRFSS collects data from random-digit-dialing telephone surveys of the non-institutionalized U.S. civilian population aged

* Corresponding author. Fax: +1 304 293 6685.
E-mail address: mhendryx@hsc.wvu.edu (M. Hendryx).

0091-7435/$ – see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1016/j.ypmed.2009.09.011

18 and over. Surveys are conducted in all states and the District of Columbia by state health departments in cooperation with the Centers for Disease Control and Prevention (CDC). The 2006 BRFSS had a median response rate of 51%. However, the large sample size, coupled with comparisons between respondents and non-respondents on key demographics indicate that non-response is not a major problem (CDC, 2007b).

Appalachia is a mountainous region of the eastern United States that extends for more than 1000 miles from southern New York to northeastern Mississippi. It includes all of West Virginia and parts of 12 additional states, and has a population of more than 26 million people. Income levels are less than national averages, and poverty rates are chronically high especially in central Appalachia. (ARC, 2008) A map of the region may be found at http://www.arc.gov/misc/arc_map.jsp.

Data

Dependent variables include dichotomous self-report measures assessing whether respondents were ever diagnosed with (1) angina or coronary heart disease (CHD), (2) heart attack or (3) stroke. A fourth general CVD category measured whether respondents reported the presence of any of these three CVD types. The morbidity categories are self-reported so an exact correspondence to diagnostic categories is uncertain; Appendix A, however, provides a link between the self-report measures and probable International Classification of Disease (ICD-10) diagnostic groupings.

Independent variables are taken from the 2006 BRFSS survey, the county-level supplementary file provided by the CDC for the 2006 survey, the Energy Information Administration (EIA) (Freme, 2008), the Area Resource File, the US Census, and the Appalachian Regional Commission (ARC, 2007).

Covariates included smoking, coded as a three-level variable: current, former (smoked at any time in the past), or lifetime non-smoker. Self-report body mass index (BMI) was coded into: underweight (BMI<18.5); normal (BMI 18.5 to <25); overweight (BMI 25 to <30); or obese (BMI 30 or greater) with the normal weight category serving as the referent. Alcohol consumption was coded as average number of drinks per day and was categorized into non-drinker, light drinker (1 or fewer drinks per day), moderate drinker (more than 1 but less than 4), or heavy drinker (4 or more per day). Light drinkers were used as the referent category.

Age was coded in years and ranged from 18 to 99. Diabetes co-morbidity was coded yes/no based on the respondent reporting ever being diagnosed with diabetes. Race/ethnicity was coded as dichotomous variables specifying African American, Native American, non-white Hispanic, Asian American, or White. Marital status was dichotomized as married or cohabitating versus any other status. Annual household income was coded as an eight-level variable from “less than $10,000” to “$75,000+”. Education was scored 1 to 6, ranging from “never attended school or only kindergarten” to “college 4 years or more (college graduate)”; a score of 4 was equivalent to a high school graduate. Metropolitan status was scored 1 to 5 with higher scores indicating a more rural environment, ranging from “in the center city of a metropolitan statistical area (MSA)” to “not in an MSA”. A final BRFSS variable was the county-level 2005 supply of office-based, general practice MDs per 100,000 persons.

The EIA was used to identify coal mining counties (Freme, 2008), defined as a county with any amount of coal mining over the years 1996–2006. Designations established by the ARC (2007) for 2006 were used to identify Appalachian counties. Then, a four-category variable was created to classify each county nationwide as Appalachian (yes/no) and coal mining (yes/no). Area Resource File data were used to find county population density measured as persons per square land mile, and US Census data were used for the percent of households receiving drinking water from private wells.

Table 1
Summary of 2006 study variables by county group, including Appalachia (yes/no) and coal mining (yes/no).

	County group				
	Appalachia, coal mining	Appalachia, no coal mining	Not Appalachia, coal mining	Not Appalachia, no coal mining	Total
N	9330	9622	9089	207,742	235,783
Number of counties	60	90	42	956	1148
% with any CVD[a]	14.4	12.0	9.2	10.0	10.2
% with angina or CHD[b]	8.7	7.0	5.3	5.7	5.8
% with heart attack	7.6	6.3	4.5	5.1	5.2
% with stroke	4.5	3.6	3.0	3.3	3.3
% female	61.0	59.8	59.2	59.5	59.6
Smoking status					
% Current	24.6	22.7	17.9	18.9	19.2
% Former	27.0	26.0	29.0	29.3	29.0
% Not a smoker	48.5	51.4	53.1	51.9	51.8
Alcohol use in last 30 days					
% None	58.4	61.4	46.2	46.1	47.2
% Light	34.9	32.6	45.4	45.1	44.2
% Moderate	6.0	5.5	7.7	8.2	8.0
% Heavy	0.7	0.6	0.5	0.7	0.7
% with diabetes	12.1	11.4	9.4	9.3	9.5
% High school education	64.0	58.3	56.1	54.5	55.1
% College education	24.0	29.5	37.4	37.4	36.5
% Married	55.9	60.9	59.9	58.7	58.7
Race/ethnicity					
% African American	3.9	7.2	3.8	8.7	8.2
% Native American	2.3	3.1	7.3	8.4	7.9
% Asian American	1.2	1.9	6.8	3.8	3.8
% Hispanic	1.2	2.0	5.3	6.5	6.1
BMI[c] category					
% Underweight	1.4	1.5	1.4	1.6	1.6
% Overweight	36.6	36.5	36.4	36.6	36.6
% Obese	30.5	28.6	26.0	25.8	26.1
Mean (SD),[d] income category	5.0 (2.2)	5.3 (2.2)	5.8 (2.1)	5.7 (2.1)	5.7 (2.1)
Mean (SD), education category	4.6 (1.0)	4.7 (1.1)	5.0 (1.0)	4.9 (1.0)	4.9 (1.1)
Mean (SD), age	52.7 (16.5)	52.1 (15.9)	51.3 (16.5)	51.7 (16.4)	51.7 (16.4)
Mean (SD), metropolitan status category	2.8 (1.4)	3.0 (1.7)	2.6 (1.7)	2.5 (1.6)	2.5 (1.5)
Mean (SD), MDs per 100,000	24.3 (7.8)	31.1 (12.3)	37.0 (12.9)	27.1 (12.6)	27.5 (12.7)

[a] CVD: cardiovascular disease.
[b] CHD: coronary heart disease.
[c] BMI: Body Mass Index.
[d] SD: Standard deviation.

Table 2
Unadjusted odds ratios (OR) and 95% confidence intervals (CI) for cardiovascular disease by Appalachia and coal mining group, 2006.

	Appalachia, coal mining, OR (95% CI)	Appalachia, no coal mining, OR (95% CI)	Not Appalachia, coal mining, OR (95% CI)
Any CVD[a]	1.52 (1.44, 1.62)**	1.23 (1.15, 1.31)**	0.91 (0.85, 0.98)*
Angina or CHD[b]	1.59 (1.48, 1.72)**	1.26 (1.16, 1.36)**	0.93 (0.85, 1.02)
Heart attack	1.53 (1.41, 1.66)**	1.25 (1.14, 1.36)**	0.88 (0.79, 0.97)*
Stroke	1.37 (1.24, 1.52)**	1.09 (0.97, 1.21)	0.89 (0.79, 1.01)

Non-mining, non-Appalachian counties serve as the referent group.
[a] CVD: cardiovascular disease.
[b] CHD: coronary heart disease.
* $p<.02$.
** $p<.0001$.

Analysis

Analyses included descriptive summaries followed by inferential analyses to examine CVD risk in coal mining areas. Models used SUDAAN Proc Multilog to account for the complex sampling design, before and after control for covariates. Models with covariates were also estimated separately by gender. Counties without mining and outside Appalachia served as the referent group for the mining variable. Variations between Appalachian and non-Appalachian mining regions in population density, and in the percent of households using well water, were subject to unpaired t-tests for group differences.

Results

We included only persons in the 50 states and the District of Columbia ($N=298{,}908$.) Missing BRFSS data reduced the final sample to 235,783 primarily due to missing income data (missing in 43,354 cases). There are 3141 US counties nationwide; 1148 (37%) are represented in the study. There are 410 Appalachian counties based on 2006 ARC designations and 150 (37%) are represented in the study; similarly, there are 139 Appalachian counties with coal mining, and 60 (43%) are represented.

Table 1 provides a summary of study variables overall and by the four county groups. Appalachian counties were characterized by higher smoking rates, lower alcohol consumption, and higher CVD rates. They had lower education and income levels, and had on average older populations. In general, these differences were more pronounced in coal mining portions of Appalachia compared to non-mining portions of the region.

Before adjusting for covariates, the odds of reporting CVD, overall and for each type, were significantly higher in Appalachian coal mining areas relative to non-Appalachian, non-mining locations (Table 2). Effects for non-mining Appalachian areas were detected for overall CVD, heart attack, and CHD, but not for stroke. Coal mining areas outside of Appalachia had significantly lower risk of total CVD and heart attack.

After covariate adjustment, risk remained significantly elevated in coal mining areas of Appalachia for overall CVD, angina or CHD, and heart attack, but not stroke (Table 3). Risk for angina or CHD remained significantly elevated in non-mining portions of Appalachia, but other forms of CVD did not. People in non-Appalachian mining areas reported significantly lower risk of heart attack. Odds ratios (ORs) were highest for the Appalachian mining counties. After adjusting for covariates, the Appalachian mining area effects remained significant ($p<0.0001$.) Most other independent variables were significantly related to CVD risk in expected ways including greater age, over-

Table 3
Full model adjusted odds ratios (OR) and 95% confidence intervals (CI) for cardiovascular disease by county group including Appalachia (yes/no) and coal mining (yes/no), 2006.

	Any CVD[a]	Angina or CHD[b]	Heart attack[c]	Stroke[d]
County category				
Non-mining, non-Appalachian	1.00	1.00	1.00	1.00
Appalachian coal-mining	1.21 (1.13, 1.30)**	1.28 (1.18, 1.39)**	1.20 (1.10, 1.31)**	1.05 (0.94, 1.17)
Appalachian non-mining	1.07 (1.01, 1.15)*	1.12 (1.03, 1.22)*	1.07 (0.98, 1.18)	0.93 (0.82, 1.04)
Coal mining, non-Appalachian	0.95 (0.88, 1.03)	0.97 (0.87, 1.07)	0.91 (0.81, 1.01)	0.93 (0.82, 1.06)
Female	0.57 (0.55, 0.58)	0.56 (0.54, 0.58)	0.44 (0.42, 0.45)	0.78 (0.74, 0.82)
Smoking status	1.43 (1.40, 1.46)	1.40 (1.37, 1.44)	1.53 (1.49, 1.57)	1.37 (1.32, 1.41)
Alcohol use categories				
Light drinker	1.00	1.00	1.00	1.00
Non-drinker	1.34 (1.29, 1.38)	1.31 (1.25, 1.36)	1.36 (1.30, 1.42)	1.44 (1.36, 1.53)
Moderate drinker	0.85 (0.79, 0.90)	0.89 (0.82, 0.96)	0.80 (0.73, 0.87)	0.84 (0.75, 0.95)
Heavy drinker	1.00 (0.83, 1.20)	0.88 (0.68, 1.12)	1.05 (0.83, 1.32)	1.24 (0.93, 1.65)
Diabetes	2.25 (2.17, 2.34)	2.21 (2.11, 2.31)	2.22 (2.12, 2.32)	1.95 (1.84, 2.07)
Education	0.97 (0.96, 0.99)	1.02 (1.00, 1.04)	0.95 (0.93, 0.97)	1.00 (0.97, 1.02)
Married	1.08 (1.04, 1.12)	1.17 (1.12, 1.22)	1.08 (1.03, 1.13)	1.03 (0.98, 1.09)
African American	0.94 (0.89, 0.99)	0.73 (0.68, 0.79)	0.88 (0.81, 0.94)	1.17 (1.08, 1.27)
Native American	1.34 (1.21, 1.48)	1.29 (1.14, 1.46)	1.30 (1.14, 1.48)	1.39 (1.19, 1.61)
Asian American	0.98 (0.90, 1.07)	0.89 (0.80, 1.00)	1.01 (0.91, 1.13)	1.17 (1.03, 1.33)
Hispanic	0.61 (0.54, 0.69)	0.62 (0.54, 0.73)	0.64 (0.54, 0.75)	0.60 (0.49, 0.72)
BMI[e] categories				
BMI normal	1.00	1.00	1.00	1.00
BMI underweight	1.32 (1.17, 1.48)	1.00 (0.85, 1.17)	1.37 (1.18, 1.60)	1.49 (1.27, 1.75)
BMI overweight	1.26 (1.21, 1.31)	1.32 (1.26, 1.38)	1.27 (1.21, 1.33)	1.09 (1.03, 1.15)
BMI obese	1.58 (1.52, 1.65)	1.75 (1.66, 1.84)	1.59 (1.50, 1.67)	1.23 (1.15, 1.31)
Income scale	0.86 (0.85, 0.87)	0.88 (0.87, 0.89)	0.87 (0.86, 0.88)	0.82 (0.81, 0.83)
Age	1.06 (1.06, 1.06)	1.06 (1.06, 1.06)	1.06 (1.06, 1.06)	1.05 (1.05, 1.05)
Metropolitan status	1.01 (1.00, 1.02)	1.02 (1.00, 1.03)	1.01 (1.00, 1.02)	0.99 (0.98, 1.01)
Physician supply	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)

[a] CVD: cardiovascular disease. Model Satterthwaite adjusted chi-square = 71,454 ($df=23$), $p<0.00001$.
[b] CHD: coronary heart disease. Model Satterthwaite adjusted chi-square = 69,870 ($df=23$), $p<0.00001$.
[c] Model Satterthwaite adjusted chi-square = 65,516 ($df=23$), $p<0.00001$.
[d] Model Satterthwaite adjusted chi-square = 62,537 ($df=23$), $p<0.00001$.
[e] BMI: Body mass index.
* $p<0.05$.
** $p<0.0001$.

Table 4
Unadjusted % with cardiovascular disease for men and women, and adjusted odds ratios (OR) and 95% confidence intervals (CI) for cardiovascular disease by Appalachia and coal mining groups, separately for women and men, 2006.

	Appalachia, coal mining		Appalachia, no coal mining		Not Appalachia, coal mining		Not Appalachia, no coal mining	
	Unadjusted % with CVD[a]	OR (95% CI)	Unadjusted % with CVD[a]	OR (95% CI)	Unadjusted % with CVD[a]	OR (95% CI)	Unadjusted % with CVD[a]	OR
Women (N = 140,444)								
Any CVD[a]	12.7	1.18 (1.08, 1.29)**	9.9	0.99 (0.90, 1.10)	8.5	1.04 (0.93, 1.16)	8.4	1.00
Angina or CHD[b]	7.5	1.25 (1.12, 1.39)***	5.9	1.11 (0.98, 1.26)	4.6	1.05 (0.91, 1.20)	4.5	1.00
Heart attack	5.9	1.17 (1.03, 1.32)*	4.4	0.98 (0.85, 1.12)	3.7	1.03 (0.89, 1.20)	3.7	1.00
Stroke	4.5	1.07 (0.93, 1.23)	3.2	0.82 (0.70, 0.96)*	3.1	0.98 (0.83, 1.16)	3.2	1.00
Men (N = 95,339)								
Any CVD[a]	17.1	1.25 (1.13, 1.38)***	15.0	1.17 (1.05, 1.29)**	10.2	0.85 (0.76, 0.97)*	12.2	1.00
Angina or CHD[b]	10.7	1.31 (1.17, 1.48)***	8.7	1.12 (0.99, 1.27)	6.3	0.89 (0.77, 1.03)	7.3	1.00
Heart attack	10.3	1.22 (1.08, 1.38)**	9.0	1.16 (1.03, 1.31)*	5.6	0.81 (0.69, 0.94)*	7.1	1.00
Stroke	4.4	1.02 (0.86, 1.21)	4.2	1.08 (0.91, 1.29)	2.8	0.86 (0.70, 1.06)	3.4	1.00

Non-mining, non-Appalachian counties serve as the referent group.
[a] CVD: cardiovascular disease.
[b] CHD: coronary heart disease.
* $p < 0.02$.
** $p < 0.003$.
*** $p < 0.0001$.

weight and obesity, smoking, diabetes, lower education, and lower income.

Persons who reported no alcohol use were at higher risk relative to light drinkers, while moderate drinkers reported lower risk. The OR for heavy drinking was not significant. An additional analysis of total CVD included only age and the drinking categories; in this analysis (results not shown), both heavy drinking and non-drinking were significantly related to higher CVD risk relative to light drinking, while moderate drinking was not significantly different.

When the Multilog models with covariates were repeated separately by gender there were significant Appalachian coal mining effects for women and men for total CVD, angina or CHD, and heart attack. Table 4 shows adjusted odds ratios for the mining variable separately by gender but does not include the detailed findings for the other covariates. This table also shows the unadjusted or crude percent of women and men with CVD by county group.

Population density was significantly higher in Appalachian coal mining counties (118.8 persons per square mile) relative to non-Appalachian mining counties (56.7 persons per square mile), $t = 3.77$, $p < 0.0002$. The percent of households relying on private wells versus treated water systems was also higher in Appalachian versus non-Appalachian mining areas, 30.1% and 17.8 %, respectively; $t = 6.37$, $p < 0.0001$.

Discussion

This study documents higher CVD morbidity for men and women in coal mining portions of Appalachia that persist after control for age, smoking, BMI, alcohol consumption, SES, and other established risks. The results suggest that environmental pollution from coal mining may be a contributing factor to population prevalence of CVD morbidity above documented Appalachian health disparities linked to behavioral and socioeconomic risks.

Coal mining effects were specific to Appalachian mining areas and were not found for mining in other parts of the country. This might reflect unmeasured confounds unique to the Appalachian population or culture that increase CVD risk. But the results might also reflect differences in environmental exposures. The population density of Appalachian coal mining areas is greater than in other coal mining regions, thereby increasing exposure potential. People live in “hollows” or narrow valleys in close proximity to mining activities in Appalachia; the topography in combination with climate and population density may serve to concentrate ambient PM or ground water exposure. Appalachian coal mining populations were also found to be significantly more reliant on private well water compared to the non-Appalachian mining population, and so may be more exposed to contamination from mining activity that impacts ground water.

Appalachian mining-related CVD effects are present for women and men, evidence that the effects cannot be attributed only to direct occupational exposure. However, the adjusted odds ratios are higher for men than for women (although these differences are not statistically significant), indicating that differential occupational exposure may have some impact on observed effects. There is also a CVD effect for men in non-mining portions of Appalachia, which might reflect behavioral risks unique to men in Appalachia, or commuting patterns which take male workers across county lines from non-mining to mining locations. Finally, men in mining areas outside Appalachia have lower CVD morbidity; we speculate that this might reflect a “healthy worker” effect or other unique demographic or behavioral characteristics of men who live in mining areas outside Appalachia.

An adjusted Appalachian mining effect was present for overall CVD and for heart attack and angina/CHD, but not for stroke. Reasons for the non-significant stroke findings are unclear but may be related to the acute nature of stroke, to the concentration of this event in older populations, or to higher levels of stroke lethality in Appalachian mining areas. Exposure to air pollution is related to increased stroke risk, but this effect seems to be particular to acute exposure episodes (Lokken et al., 2009; Szyszkowicz, 2008). Previous research on the topic of population health in coal mining areas has documented stronger mining effects for chronic forms of illness rather than acute illness (Hendryx, 2009; Hendryx and Ahern, 2008). Stroke may also be more highly dependent on age or other sociodemographic variables that overpower the relatively smaller effects of contaminants from the mining industry for this particular illness event.

Study limitations include the lack of direct environmental quality data, and the cross-sectional design. Longitudinal assessments of CVD development in relation to mining exposure are warranted. The results suggest the need for environmental assessments to confirm whether these associations are the result of pollution from the mining industry. There is evidence from other sources, however, that air and water quality are impaired around coal mining activity in Appalachia or elsewhere. (Ghose and Majee, 2007; McAuley and Kozar, 2006). The finding that non-drinking was related to higher CVD risk does not necessarily mean that drinking is protective; persons diagnosed with CVD may subsequently choose to stop drinking as a health protection behavior.

The survey was conducted in 2006 and coal mining was measured for the years 1996–2006. The environmental impact on the development of CVD occur over the long term (Ferreccio et al., 2000; Miller et al., 2007; Pope et al., 2002), but some effects may be more immediate (Wellenius et al., 2006). A mining county in 1 year is almost always a mining county in other or all other years (Freme, 2008) so 1996–2006 is (1) a reasonable proxy of mining in 2006 and (2) appropriate to include to the extent that environmental mining effects are delayed.

Because the BRFSS data are based on self-report, people who reported they had experienced a heart attack or stroke had to have survived it. If people in isolated Appalachian areas who experienced these events were more likely to die from them, mining-related effects could be underestimated. This is a possible explanation for the lack of a mining-effect for the stroke variable. Previous research has documented higher mortality rates for CVD in mining areas (Hendryx, 2009).

The results of this study and others that document mining-related health disparities have implications for environmental policy as disease prevention. For example, the West Virginia Department of Environmental Protection (DEP) maintains 22 air monitoring stations that assess standard ambient air quality indicators including PM2.5, ozone, sulfur dioxide and others (Benedict, 2008). These stations are located in 13 of West Virginia's 55 counties; none of the monitors are located in communities that are defined primarily by coal mining activity. Establishing new monitoring stations in coal mining towns would be one policy initiative to address environmental quality in coal mining locations.

More comprehensive assessments of water quality may also be undertaken. Using West Virginia as an example again, the current protocol for well water testing is that routine DEP tests occur in response to citizen requests, but tests are limited to bacteriological screens, not metals or compounds. Another environmental policy change would include tests for metals and compounds when residents express concerns for well water quality that may be impacted by mining activity. These recommendations pertain not only to West Virginia but other mining communities where impaired air and water quality adversely impact human health.

Finally, regardless of the relative impacts of environmental, behavioral or socioeconomic factors on CVD, the results document that the geographic areas of Appalachia where CVD is highest are in the coalfields. To achieve the stated objective of the National Institutes of Health to reduce and eliminate disparities in Appalachia relative to the nation (Zerhouni and Ruffin, 2002), disease prevention efforts should be focused on coal mining portions of the region.

Conflict of interest statement

None.

Appendix A

List of approximate International Classification of Disease (ICD-10) codes corresponding to self-reported morbidity categories on the 2006 Behavioral Risk Factor Surveillance System (BRFSS).

Self-reported morbidity	Approximate corresponding ICD-10 codes
Angina or coronary heart disease	I20, I24, I25
Heart attack	I21, I22
Stroke	I60-I64

References

ARC, 2007. Appalachian Regional Commission. Retrieved 08-17-07, from http://www.arc.gov/index.jsp.

ARC, 2008. Appalachian Region Economic Overview. Retrieved 11-14-08, from http://www.arc.gov/index.do?nodeId=26.

Benedict, J.A., 2008. Air Quality Annual Report, 2007. West Virginia Department of Environmental Protection, Charleston, WV.

Bhatnagar, A., 2006. Environmental cardiology: studying mechanistic links between pollution and heart disease. Circ. Res. 99, 692–705.

CDC, 2007a. Behavioral Risk Factor Surveillance System. Retrieved 07-11-07, from http://www.cdc.gov/brfss/index.htm.

CDC, 2007b. BRFSS: 2006 Behavioral Risk Factor Surveillance System Summary Data Quality Report. May 3, 2007. Retrieved 03-26-09, from ftp://ftp.cdc.gov/pub/Data/Brfss/2006SummaryDataQualityReport.pdf.

Darmon, N., Drewnowski, A., 2008. Does social class predict diet quality. Am. J. Clin. Nutr. 87, 1107–1117.

Ferreccio, C., Gonzalez, C., Milosavjlevic, V., Marshall, G., Sancha, A.M., Smith, A.H., 2000. Lung cancer and arsenic concentrations in drinking water in Chile. Epidemiology 11, 673–679.

Freme, F., 2008. Coal Industry Annuals / Annual Coal Reports. Retrieved 05-19-08, from http://www.eia.doe.gov/cneaf/coal/page/acr/backissues.html.

Galimanis, A., Mono, M.L., Arnold, M., Nedeltchev, K., Mattle, H.P., 2009. Lifestyle and stroke risk: a review. Curr. Opin. Neurol. 22, 60–68.

Ghose, M.K., 2007. Generation and quantification of hazardous dusts from coal mining in the Indian context. Environ. Monit. Assess. 130, 35–45.

Ghose, M.K., Majee, S.R., 2007. Characteristics of hazardous airborne dust around an Indian surface coal mining area. Environ. Monit. Assess. 130, 17–25.

Halverson, J.A., Bischak, G., 2007. Underlying socioeconomic factors influencing health disparities in the Appalachian region. Department of Community Medicine, West Virginia University, Morgantown, WV.

Harwood, G.A., Slasberry, P., Ferketich, A.K., Wewers, M.E., 2007. Cigarette smoking, socioeconomic status, and psychosocial factors: examining a conceptual framework. Public Health Nurs. 24, 361–371.

Hendryx, M., 2008. Mortality rates in Appalachian coal mining counties: 24 years behind the nation. Environ. Justice 1, 5–11.

Hendryx, M., 2009. Mortality from heart, respiratory, and kidney disease in coal mining areas of Appalachia. Inter. Arch. Occup. Environ. Health 82, 243–249.

Hendryx, M., Ahern, M., 2008. Relations between health indicators and residential proximity to coal mining in West Virginia. Am. J. Public Health 98, 669–671.

Hendryx, M., O'Donnell, K., Horn, K., 2008. Lung cancer mortality is elevated in coal mining areas of Appalachia. Lung Cancer 62, 1–7.

Kolker, A., Palmer, C.A., Bragg, L.J., Bunnell, J.E., 2006. Arsenic in coal. Fact sheet 2005-3152. U.S. Geological Survey, Reston, VA.

Lokken, R.P., Wellenius, G.A., Coull, B.A., et al., 2009. Air pollution and risk of stroke: underestimation of effect due to misclassification of time of event onset. Epidemiology 20, 137–142.

Marmot, M., Wilkinson, R.G. (Eds.), 2005. Social Determinants of Health, 2nd ed. Oxford University Press, Oxford.

Mastin, J.P., 2005. Environmental cardiovascular disease. Cardiovasc. Toxicol. 5, 91–94.

McAuley, S.D., Kozar, M.D., 2006. Ground-water quality in unmined areas and near reclaimed surface coal mines in the northern and central Appalachian coal regions, Pennsylvania and West Virginia. US Department of the Interior US Geological Survey.

Miller, K.A., Siscovick, D.S., Sheppard, L., et al., 2007. Long-term exposure to air pollution and incidence of cardiovascular events in women. N. Engl. J. Med. 356 (5), 447–458.

Pope, C.A., Burnett, R.T., Thun, M.J., et al., 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA 287, 1132–1141.

Szyszkowicz, M., 2008. Ambient air pollution and daily emergency department visits for ischemic stroke in Edmonton, Canada. Int. J. Occup. Med. Environ. Health 21, 295–300.

Wellenius, G.A., Schwartz, J., Mittleman, M.A., 2006. Particulate air pollution and hospital admissions for congestive heart failure in seven United States cities. Am. J. Cardiol. 97, 404–408.

Wood, L.E., 2005. Trends in national and regional economic distress: 1960–2000. Appalachian Regional Commission, Washington DC.

Woolf, S.H., Johnson, R.E., Geiger, H.J., 2006. The rising prevalence of severe poverty in America: a growing threat to public health. Am. J. Prev. Med. 31, 332–341.

WVGES, 2007. Trace elements in West Virginia Coals. Retrieved 10-06-07, from http://www.wvgs.wvnet.edu/www/datastat/te/index.htm.

Zerhouni, E.A., Ruffin, J., 2002. Strategic research plan and budget to reduce and ultimately eliminate health disparities. Volume I: Fiscal Years 2002-2006: National Institutes of Health, US Department of Health and Human Services.