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Self-Reported Cancer Rates in Two Rural Areas of West Virginia with and Without Mountaintop Coal Mining

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Abstract Mountaintop coal mining in the Appalachian region in the United States causes significant environmental damage to air and water. Serious health disparities exist for people who live in coal mining portions of Appalachia, but little previous research has examined disparities specifically in mountaintop mining communities. A community-based participatory research study was designed and implemented to collect information on cancer rates in a rural mountaintop mining area compared to a rural non-mining area of West Virginia. A door–door health interview collected data from 773 adults. Self-reported cancer rates were significantly higher in the mining versus the non-mining area after control for respondent age, sex, smoking, occupational history, and family cancer history (odds ratio = 2.03, 95% confidence interval = 1.32–3.13). Mountaintop mining is linked to increased community cancer risk. Efforts to reduce cancer and other health disparities in Appalachia must focus on mountaintop mining portions of the region.

Keywords Mountaintop coal mining · Cancer · Community-based participatory research · West Virginia

Bo Webb—2010 Purpose Prize Winner.

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Introduction

Morbidity and mortality rates in Appalachia for many forms of disease including cancer exceed those in the rest of the United States [1–6]. The National Institutes of Health identifies Appalachia as a region with significant and persistent health disparities requiring focused research attention [4]. Within Appalachia, recent evidence indicates that public health disparities are concentrated within coal mining portions of the region, especially within Central Appalachia where mountaintop coal mining activities take place [7–14]. Appalachian disparities include elevated population cancer mortality rates in mining areas [12–15].

Mountaintop mining (MTM), which is also called mountaintop removal mining, uses heavy machinery and explosives to strip vegetation and remove topsoil and rock to reach coal seams. The spoil from this activity is deposited in adjacent valleys that contain headwater streams. As of 2005, mountaintop mining had impacted 272,000 acres in southern West Virginia, eastern Kentucky, eastern Tennessee, and western Virginia [16]. MTM is a public health concern because of the serious and long lasting environmental damage that it causes [17–19]. One recent study found that 9 out of 10 Appalachian streams downstream from mining operations are contaminated with runoff from surface mining sites, [17] and a 2010 memorandum from the Environmental Protection Agency states that 2,000 miles of Appalachian streams have been filled by surface mining practices [19]. Surface water and ground water around MTM activity are characterized by elevated sulfates, iron, manganese, arsenic, selenium, hydrogen sulfide, lead, magnesium, calcium and aluminum; contaminates severely damage local aquatic stream life and can persist for decades after mining at a particular site ceases [18, 20]. In addition, elevated levels of airborne particulate matter around surface mining operations include ammonium nitrate, silica, sulfur compounds, metals, benzene, carbon monoxide, polycyclic aromatic hydrocarbons, and nitrogen dioxide [21, 22]. Residents near MTM sites complain of health concerns, air and water contamination, reduced property values and damaged family cemeteries, and experience psychological stress from fears of floods, landslides, flyrock, and the destruction of their natural heritage [23, 24]. State political figures support the coal industry and have done little to investigate or respond to citizen concerns [23, 25–27].

Previous research on the public health impacts of coal mining in Appalachia has been limited to county-level exposure data and sometimes to county aggregate statistics. In contrast, the current study gathered person-level health data from a smaller geographic community directly impacted by mountaintop mining, compared to a community without mining. The study uses a community-based participatory research approach to test the hypothesis that residents in the MTM community will report personal cancer history at significantly higher rates than residents of the non-mining community.

Methods

Community Participatory Research

The study used a community-based participatory research (CBPR) approach. Local residents in mountaintop mining areas of West Virginia identified the problem based on their personal experiences and the experiences of their neighbors. They witnessed, for example, the explosions at the mining sites and the dust that subsequently settled over their porches, windows and gardens. They collected bottles of well water from their kitchen taps that were black with impurities from coal treatment settling ponds. Concerns about the health impacts from these conditions led them to contact a university researcher for assistance. The researcher and community members worked together to identify the study focus, develop the approach, plan the logistics, recruit interviewers for a door–door survey, conduct the survey, collect and analyze the data, and report the results. Throughout the process, the importance of maintaining objectivity and using the best possible survey instruments and methods was emphasized by all parties.

Design and Setting

The study was a cross-sectional comparison of two groups of adults aged 18 and over residing in rural southern West Virginia. One group consisted of residents along a section of the Coal River in Boone and Raleigh Counties, an area characterized by extensive activities of the coal mining industry including mountaintop mining. For 2009, over 34 million tons of coal were extracted from these two counties, including over 17 million tons from surface mining operations [28]. The second group consisted of residents in the southern portion of Pocahontas County, an area without coal mining. Figure 1 shows a map of the two study areas.

Inclusion Criteria

Eligible subjects were at least 18 years old, a resident of the household being surveyed, English speaking, and gave verbal consent to participate. To maintain subject anonymity written consent was not required. The study was reviewed and approved by the university's Institutional Review Board.

Data Collection

Data collection took place over a 3 week period in March 2011. Interviewers covered the entire study areas door–door and attempted to contact each household at least once. Business establishments and institutional settings such as nursing homes were not included. Contact attempts took place primarily during daylight hours on Monday-Friday of the sampling weeks. Interviewers traveled in pairs and were escorted in motor vehicles driven by local volunteers who knew the area.

Interviewers were undergraduate students from several regional colleges and universities who volunteered to conduct the surveys as a service project during their spring break week. Three groups of students participated in the surveying, one group/week. Approximately 10–20 students participated each week. Each group received a half-day training on the Sunday before the first survey day. The training was led by a professional trainer with participation from the principal investigator and local residents, and consisted of background information on local culture, maintaining personal safety, conflict avoidance, and survey and data recording procedures including survey practice activities. Training emphasized the importance of objectivity and accuracy in data collection. Debriefing sessions were held after each sampling day to discuss experiences and clarify procedures.

After a subject agreed to be surveyed, the questions were read to the subject and the responses were recorded on the paper interview form by an interviewer. If more than 1 eligible person was home at the time of the survey, all eligible household residents were invited to take part. Household contacts were recorded so that multiple persons within households could be identified for data analysis using hierarchical statistical methods.

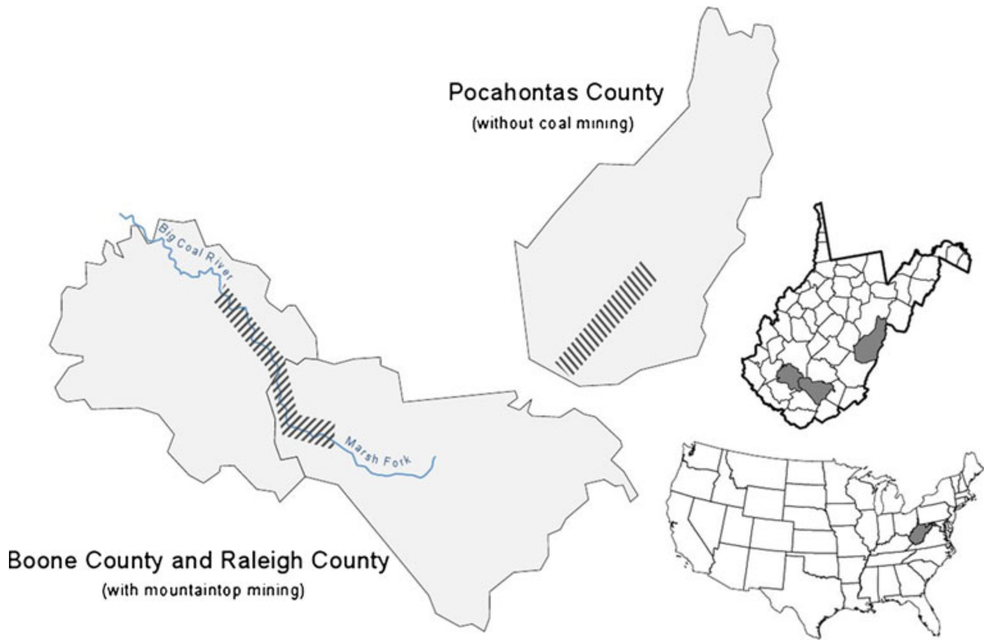

Fig. 1 Map of study areas. Cross-hatched areas indicate the approximate locations of survey activities

Response rate data were collected by recording the result of each household contact: no answer, household declined to participate, or one or more residents agreed to be surveyed.

Measures

Survey questions were drawn primarily from two pre-existing instruments that have been widely used and validated, the Behavioral Risk Factor Surveillance System (BRFSS) and the National Health Interview Survey (NHIS) family cancer history module [29, 30]. BRFSS items included self-reported lifetime cancer survivorship, tobacco use, and age. NHIS questions included the presence of cancer in related family members (mother, father, brothers, sisters, sons and daughters.) Total family size was calculated as the sum of mother, father, plus all sisters, brothers, sons and daughters, whether living or deceased. Additional items were prepared for this study including length of time living in the Coal River or Pocahontas area, and whether the subject had ever worked as a coal miner. Subject sex was also recorded. The principal investigator and the community partners made the decision to keep the survey brief so that as many surveys as possible could be collected in the limited available time; other questions that might have been asked (e.g., diet, physical activity) were therefore not included.

The BRFSS question on cancer survivorship is, "Have you ever been told by a doctor, nurse, or other health professional that you had cancer?" Subjects who answered yes to this question were asked follow-up questions including the type of cancer they had, how old they were when they were diagnosed with cancer, and whether or not they were living in Coal River or Pocahontas County at the time of diagnosis. If a subject reported more than one type of cancer, only the earliest cancer diagnosis was reported per the BRFSS protocol.

Smoking status was measured as two dummy variables including current smoker (yes/no) or former smoker (yes/no), with lifetime never smoker used as the referent in regression models. Smokeless tobacco use as measured on the BRFSS was limited to current use (yes or no).

Analysis

Number of household contacts was recorded. The response rate to the survey was calculated as a percent of household contacts with 1 or more completed surveys. Summaries of variables were calculated and frequencies and means were compared between groups using chi-square or two-tailed *t* tests. The primary dependent variable for inferential analysis was a dichotomous measure indicating whether the subject had ever had cancer. Descriptive summaries of cancer types were recorded but small numbers for any given type prevented more detailed statistical analysis of type. Unadjusted cancer rates between the two study groups were compared using a χ^2 test. Then, cancer diagnosis (yes/no) was modeled as a function of study group (Coal River or Pocahontas) controlling for subject age, sex, current and former smoking status, smokeless tobacco use, whether the subject had ever worked as a coal miner, and family history of cancer (whether or not one or more family members had ever been diagnosed with cancer.) SAS 9.2 Proc Surveylogistic was used for the modeling, nesting individuals within households.

Results

Sample Size and Response Rate

Interviewers attempted contacts at 2,679 households. A household member answered the door on 44.9% of contact attempts or 1,202 households. A total of 773 individuals from 702 households completed the survey, although, missing data on items reduced the available sample size for some analyses. The response rate to the survey was thus 58.4% of all household contacts (702/1,202).

There were four missing responses to the question on cancer survivorship, reducing the sample to 769. Of these, there were 409 surveys from Coal River and 360 from Pocahontas.

Univariate Summary

A descriptive summary of study variables is provided in Table 1. The two community groups did not differ significantly on percent female, current or former smoking status, smokeless tobacco use, age, family size, or percent family members with cancer. The groups were different on three variables. First, respondents in the Coal River area were more likely to have had occupational experience as a coal miner. Second, respondents in Coal River had lived on average in Coal River for more years than respondents in Pocahontas had lived in Pocahontas. The bivariate correlation between age and years living in the community was 0.67 and so only age was used as a covariate in the regression models reported below.

The third difference between the two groups was that Coal River respondents reported personal diagnoses of cancer at higher rates: 14.4% ($N = 59$) of respondents in Coal River compared to 9.4% ($N = 34$) in Pocahontas ($\chi^2 = 4.47$, $df = 1$, $P < 0.035$). There was no significant difference in age at cancer diagnosis between the two groups. Of the 59 Coal River respondents with cancer, only two (3%) were not living in Coal River at time of diagnosis; in Pocahontas, 7 of the 34 respondents with cancer (21%) were not living in Pocahontas at time of diagnosis (Fisher's exact test for small samples two-sided $P < 0.02$).

Table 2 provides a descriptive summary of the types of cancers reported by respondents in both locations. The higher number of total cancer cases in Coal River are due to greater counts of cancers of several types including uterine and ovarian, skin, urinary, and "other" cancers. ("Other" included bone, brain, other, or unknown types.)

Table 1 Summary of respondent characteristics in Coal River and Pocahontas County

	Coal River ($N = 409$)[a] *N* (%)	Pocahontas ($N = 360$) *N* (%)
Diagnosed with cancer[b]	59 (14.4)	34 (9.4)
Female[c]	224 (54.8)	200 (55.7)
Current smoker[c]	131 (32.2)	112 (31.6)
Former Smoker[c]	107 (26.4)	109 (30.8)
Smokeless tobacco use[c]	58 (14.2)	40 (11.2)
One or more family members with cancer[c]	234 (57.2)	216 (60.0)
Occupational history as a coal miner[d]	130 (31.8)	16 (4.4)
	Mean (sd)	Mean (sd)
Age in years[c]	56.0 (19.9)	57.3 (17.9)
Duration in years living in Coal River or Pocahontas[d]	45.1 (23.0)	39.8 (24.3)
Family size[c]	7.9 (3.8)	7.8 (3.9)

[a] Missing data reduces sample size for individual variables

[b] $\chi^2 = 4.47$, $df = 1$, $P = 0.0345$

[c] Groups not significantly different

[d] Groups significantly different, $P < 0.05$ on χ^2 or two-tailed t test

Table 2 Number of cancer cases by type reported in Coal River and Pocahontas

Cancer type	Coal River ($N = 409$)	Pocahontas ($N = 360$)	Total
Breast	6 (1.5)	6 (1.7)	12
Cervical	8 (2.0)	6 (1.7)	14
Other female reproductive (uterine and ovarian)	5 (1.2)	1 (0.3)	6
Male reproductive	3 (0.7)	5 (1.4)	8
Head and neck	2 (0.5)	1 (0.3)	3
Gastrointestinal	3 (0.7)	3 (0.8)	6
Leukemia	0	1 (0.3)	1
Melanoma	4 (1.0)	2 (0.6)	6
Other skin	13 (3.2)	4 (1.1)	17
Lung	0	2 (0.6)	2
Urinary	8 (2.0)	2 (0.6)	10
Others	7 (1.7)	1 (0.3)	8
Total	59 (14.4)	34 (9.4)	93

Figures in parentheses are the percent of total cases in the Coal River or Pocahontas group

Table 3 Results of nested logistic regression model, odds of reporting cancer

Independent variable	Odds ratio	95% Confidence interval
Residence in Coal River	2.03	1.32, 3.13
Age	1.04	1.02, 1.05
Female	1.11	0.63, 1.95
Current smoker	2.09	1.17, 3.73
Former smoker	2.21	1.23, 3.97
Current smokeless tobacco use	0.60	0.25, 1.45
Occupational experience as a coal miner	0.53	0.24, 1.21
Family history of cancer	1.91	1.19, 3.06

Logistic Regression Model Results

After controlling for the effects of covariates, Coal River subjects reported a significantly higher odds of cancer (Table 3). The odds ratio (OR) was 2.03 (95% CI = 1.32, 3.13.) The analysis was based on $N = 756$ after deleting 13 cases with missing data on independent variables. Other significant effects on cancer risk were age, current or former smoking, and family history of cancer.

To test the sensitivity of findings, we re-conducted the models twice, after re-coding two specific forms of cancer. First, we counted the cervical cancer cases with the non-cancer group, because of the evidence that most cervical cancer results from exposure to human papillomavirus (HPV). Second, we counted the non-melanoma skin cancer cases with the non-cancer group. The ORs for cancer remained significantly higher in the Coal River group after recoding cervical cancer (OR = 2.30, CI = 1.43, 3.71) and after recoding non-melanoma skin cancer (OR = 1.83, CI = 1.11, 3.03).

Discussion

This is the first person-level study of adult health status on a small geographic scale (i.e., smaller than county) in an environment characterized by mountaintop coal mining. The odds for reporting cancer were twice as high in the mountaintop mining environment compared to the non-mining environment in ways not explained by age, sex, smoking, occupational exposure, or family cancer history. No one type of cancer was responsible for the effect.

Environmental pollution contributes to cancer risk [31–35], and many chemicals that are present in coal, coal strata, and coal processing activities are established or possible carcinogens. Arsenic, for example, is an impurity present in coal that is implicated in many forms of cancer including that of skin, bladder and kidney [31, 36]. Cadmium is linked to renal cancer [34]. Diesel engines are widely used at mining sites, and diesel fuel is used for surface mining explosives, coal transportation and coal processing; diesel exhaust has been identified as a major environmental contributor to cancer risk [37].

Previous research on Appalachian health disparities has tended to focus on health care access problems, or behavioral risks such as poor diet and smoking, as the causal factors driving poor health outcomes. A recent study in Virginia, for example, identified higher cancer rates among Appalachian compared to non-Appalachian residents, and discussed the need for better health care in Appalachia [5]. However, Appalachian Virginia also has mountaintop coal mining, and the environmental, social and economic impacts of coal mining are often overlooked in Appalachian health research. Mountaintop coal mining is damaging to the environment, and contributes to the area's chronic economic problems; these areas have the highest poverty rates and highest unemployment rates in the region [9, 38]. Poor economic conditions are one of the most powerful predictors of poor public health outcomes [39, 40].

Study limitations include those relating to survey sampling procedures and the extent of questions asked. Contact attempts at most households occurred only once, and survey times did not include late evenings and weekends because of the logistical and cost difficulties involved in transporting and housing the student volunteers. This could result in survey respondents in both locations that are not necessarily representative of the entire populations. Survey procedures, however, were comparable in both communities and so would not be expected to result in an overestimate of cancer in Coal River relative to Pocahontas. Asking people if they have ever had cancer limits the cancer experience to survivors. Information on persons who died from cancer was not collected, which may explain why some cancer types such as lung cancer were observed rarely in the sample. In other research, higher lung cancer mortality in coal mining portions of Appalachia has been documented [10].

The survey included limited information on covariates. The preference among the community research partners was to keep the survey brief so that as many surveys as possible could be collected in a short time. There were concerns expressed by community partners that if the time spent per survey was prolonged, such that fewer surveys could be completed/day and more time had to be spent in Coal River to collect an adequate sample size, word about the survey taking place would reach the coal industry, and community residents would be instructed or pressured by industry representatives not to take part. Limited covariate data precluded investigating the possible impacts of such variables as obesity or health care access on cancer.

After data collection the research partners convened to discuss how the study process could be improved for possible replication in other communities. There was agreement that future efforts should attend to data collection during weekend and evening times, and how some additional data would have been worth the extra survey time to collect. In addition to extra covariates such as obesity, community partners expressed the importance in future studies of collecting cancer data not just on biologically-related family members but on spouses, as they knew of cases where a husband or wife had recently died of cancer, but these data were not collected in the survey. These discussions illustrate the utility of the community-based participatory model in helping both parties (academic researchers and community residents) learn from each other to make research efforts more practical and effective.

As a partial response to the limited covariate data, we compared Boone, Raleigh and Pocahontas counties on poverty, health care access and obesity rate indicators. Data from the US Department of Agriculture Food Atlas indicate similar adult obesity rates in the three counties: 32.4% in Pocahontas, 31.3% in Raleigh, and 33.6% in Boone [41]. Poverty rates for 2007 as reported in the 2008 Area Resource File were 15.7% for Pocahontas, 16.7% for Raleigh, and 18.2% for Boone [42]. Pocahontas County was not designated as a Health Professions Shortage Area for 2008, Boone County was designated as a shortage area, and Raleigh County was a partial shortage area [40]. Although, these differences indicate that environmental effects are not the only influence on health outcomes, they also highlight the economic and health care problems that are present in disadvantaged mining environments.

Pocahontas County was chosen for the comparison location because it is in southern West Virginia and does not have active coal mining, but otherwise was selected due to personal contacts among the community research partners. Future research that surveys community health in more closely matched mining and non-mining communities could reveal a better understanding of comparative health in coal mining and non-coal mining towns. Further person-level comparisons between communities of traditional coal mining practices versus mountaintop mining practices could also yield better understanding of the effects of coal mining on the health of Appalachian communities.

The higher cancer rates in Coal River cannot be attributed to direct occupational exposures among coal miners. In fact, former or current coal miners who completed the survey did not have higher cancer rates than non-miners, perhaps reflecting a ‘healthy worker’ phenomenon.

The National Cancer Institute (NCI) reported that in 2007 about 3.9% of the US population consisted of cancer survivors (excluding non-melanoma skin cancer) [43]. Rates in the current study excluding non-melanoma skin cancer were 9.9% across groups; that is, there was a high cancer rate in both groups compared to the national average. However, a report published by the state of West Virginia estimated that 10.4% of adults in the state were cancer survivors in 2009 [44], which is close to the rate found in Pocahontas. The state report also says, however, that the US prevalence rate is 9.6% without citing the source for this figure; the national rate in this state document does not agree with the NCI report.

Conclusions and Next Steps

There are 1.2 million people who live in mountaintop coal mining counties in central Appalachia based on 2010 US Census data. If the rates found in this study represent the region, a 5% higher cancer rate (14.4% vs. 9.4%) translates to an additional 60,000 people with cancer in central Appalachian mountaintop mining counties. On a national level, the difference between 11.2 and 3.9% (the rates in the Coal River sample and the US, respectively, not including non-melanoma skin cancers) translates to an additional 87,600 people with cancer in central Appalachian mountaintop mining areas compared to national rates. Although, these projections are uncertain, they illustrate the large numbers of people who are potentially impacted by mountaintop mining environments.

The people of Appalachia constitute a nationally recognized priority population for the elimination of health disparities [4]. The results of this study and others previously cited on coal mining populations demonstrate that health disparities are concentrated in mountaintop mining areas of the region; clearly, the national goal to eliminate Appalachian health disparities will not be achieved unless disparities are eliminated in mountaintop mining areas.

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