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Personal and Family Health in Rural Areas of Kentucky With and Without Mountaintop Coal Mining

Michael Hendryx, PhD

Department of Health Policy, Management and Leadership, School of Public Health, West Virginia University, Morgantown, West Virginia

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For further information, contact: Michael Hendryx, PhD; PO Box 9190; Morgantown, WV 26506; e-mail: mhendryx@hsc.wvu.edu.

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Abstract

Purpose: This study investigates health disparities for adults residing in a mountaintop coal mining area of Appalachian Kentucky. Mountaintop mining areas are characterized by severe economic disadvantage and by mining-related environmental hazards.

Methods: A community-based participatory research study was implemented to collect information from residents on health conditions and symptoms for themselves and other household members in a rural mountaintop mining area compared to a rural nonmining area of eastern Kentucky. A door-to-door health interview collected data from 952 adults. Data were analyzed using prevalence rate ratio models.

Findings: Adjusting for covariates, significantly poorer health conditions were observed in the mountaintop mining community on: self-rated health status, illness symptoms across multiple organ systems, lifetime and current asthma, chronic obstructive pulmonary disease, and hypertension. Respondents in mountaintop mining communities were also significantly more likely to report that household members had experienced serious illness, or had died from cancer in the past 5 years. Significant differences were not observed for self-reported cancer, angina, or stroke, although differences in cardiovascular symptoms and household cancer were reported.

Conclusions: Efforts to reduce longstanding health problems in Appalachia must focus on mountaintop mining portions of the region, and should seek to eliminate socioeconomic and environmental disparities.

Key words Appalachia, environmental determinants of health, health disparities, rural, social determinants of health.

Appalachia is the forested, mountainous, largely rural region of the eastern United States extending from southern New York to northeastern Mississippi. People who live in Appalachia experience significant health disparities relative to the nation including disparities in cancer, heart disease and other chronic illnesses.[1-6] However, not all Appalachian areas are the same, and health problems are most concentrated in portions of central and southern Appalachia. Within central Appalachia specifically, evidence indicates that public health disparities (ie, cancer, cardiovascular disease, lung disease, birth defects, and health-related quality of life) are concentrated in areas where mountaintop coal mining activities take place.[7-12] The causes of health problems in mining communities are complex and include in part the persistent socioeconomic disparities present in mining-dependent economies,[13,14] but they may also include environmental air and water pollution that result from these large surface mining operations.

Mountaintop mining (MTM), which is also called mountaintop removal mining, is a form of large-scale surface coal mining practiced in central Appalachia (southern West Virginia, eastern Kentucky, eastern Tennessee, and western Virginia.) The central Appalachian coalfields cover an area about 12 million square acres.[15] MTM uses heavy machinery and explosives to remove forests, topsoil, and rock to reach coal seams. This activity occurs in proximity to residential communities. Forests are typically clear-cut and burned. The removed rock and soil is deposited in adjacent valleys that contain headwater streams. MTM is estimated to have buried about 4,000 stream kilometers as of 2012.[15] MTM is a public health concern because of the widespread, serious and long-lasting environmental damage that it causes.[16-19] Exposure of previously buried rock and coal minerals to water and oxygen results in a continuous discharge of sulfates and trace metals that lasts for decades.[17] Surface water emerging from MTM mining sites, or present in ground water proximate to mining, is characterized by elevated sulfates, iron, manganese, arsenic, selenium, hydrogen sulfide, lead, magnesium, calcium, and aluminum; pollutants severely damage aquatic stream life and persist for decades after mining at a particular site ceases.[17-20] In addition, airborne particulate matter around surface mining operations includes elevated levels of ammonium nitrate, silica, sulfur compounds, metals, benzene, carbon monoxide, polycyclic aromatic hydrocarbons, and nitrogen dioxide.[21-23] Some of these environmental contaminants have been found in other research to increase risk for the types of health problems that have been observed in MTM communities.[24-28]

Most published studies on health disparities in coal mining communities have relied on secondary data analyses. In addition, some of the studies used aggregate county statistics rather than person-level data. An exception to this pattern was a study that reported on results of a door-to-door health survey among residents of a mountaintop coal mining community in West Virginia; this study documented higher self-reported cancer rates than residents from a nonmining community.[29] The current study extends prior research by conducting a door-to-door survey in a second community, by including additional covariates to provide better control for other health risks, and by examining multiple additional health outcome measures not only for respondents themselves but also, for the first time, as reported by respondents for the health of other household members. The hypothesis is tested that self-reported personal and family health outcomes will be significantly worse in the MTM community compared to the nonmining community, adjusting for covariates.

Methods

Design and Setting

The study was a cross-sectional comparison of 2 groups of adults aged 18 and over residing in Appalachian rural eastern Kentucky. The university investigator partnered with local community groups to design and implement the study according to community-based participatory research principles.[30]

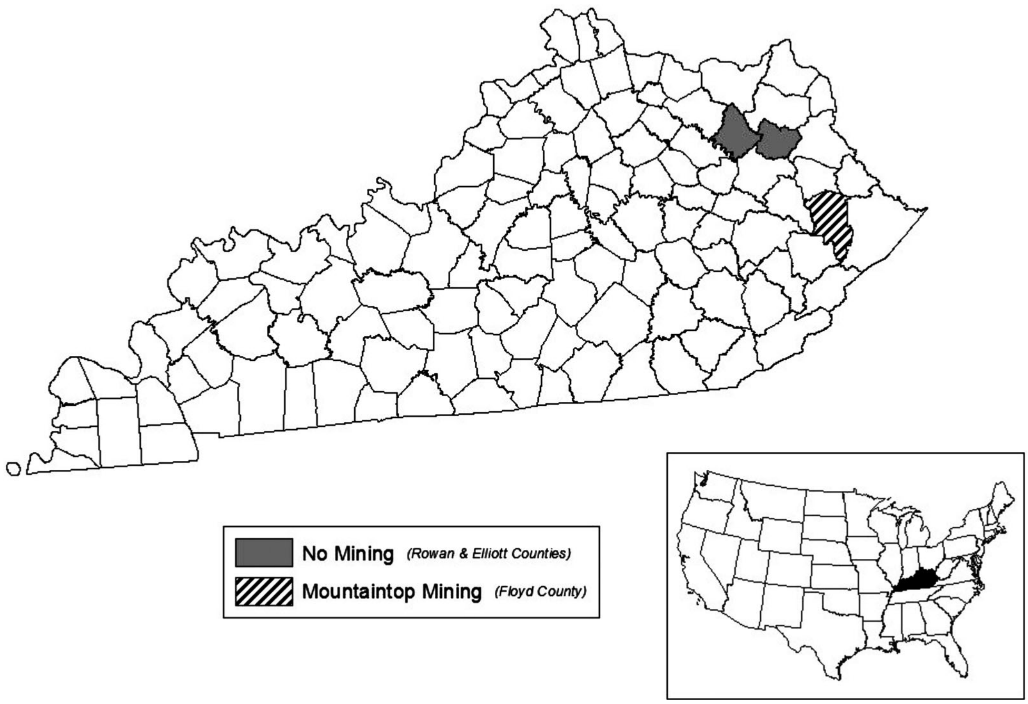
Table 1 Population Characteristics of Mountaintop Mining and Nonmining Groups

	Floyd (Mountaintop Mining)	Elliott/Rowan (No Mining)
Population size	39,207	31,289
Poverty rate	28.1	31.5
Median household income	$27,907	$29,262
Percent with high school education	68.9	75.1
Percent with college education	11.7	20.4
Percent 65 years and over	13.8	12.9
Metropolitan or micropolitan statistical areas	None	None

One group of adult survey participants consisted of residents in Floyd County, an area characterized by extensive activities of the coal mining industry including MTM. In 2010, over 1.5 million tons of coal were extracted from this county, including over 1 million tons from surface mining operations.[31] In the entire mining area of eastern Kentucky, there was a total of 68 million tons mined in 2010 including over 33 million tons from surface mines. (These figures represent a decline in production over previous years; eastern Kentucky production in 2008, for example, totaled over 90 million tons.) The second group consisted of residents in 2 rural nonmining counties in eastern Kentucky, Elliott and Rowan Counties. These counties were selected partly for logistic reasons so that the survey could be conducted in counties close together, and partly to survey from mining and nonmining locations with similar population demographics. Elliott and Rowan Counties were combined to approximate a population size similar to Floyd County from which to draw a sample. Table 1 shows population characteristics of the 2 study areas as drawn from the US Census; the poverty rate is slightly higher in the nonmining area, but the nonmining area also has slightly higher median income levels and education levels. Figure 1 shows a map of the study areas.

Detailed maps of the 3 study counties that contained all roads and structures (households and other buildings) were examined in consultation with local residents to plan the sampling strategy. Households are generally clustered in hollows, which are narrow valleys containing rivers or streams. During the course of the sampling weeks a record was made of which specific hollows were visited each day. Over the course of the sampling period, every hollow and every community was canvassed at least once, in an effort to reach every household. The sampling strategy was not otherwise stratified or selected;

Figure 1 Map of Study Areas.



rather, day-to-day sampling plans were developed so that every household was contacted at least once over the course of the sampling period.

Inclusion Criteria

Eligible participants 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 2-week period in March 2012. Interviewers covered the study areas door-to-door and contacted 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; however, surveying also occurred in the early evening hours and on Saturdays. Interviewers traveled in pairs and were escorted in motor vehicles driven by local volunteers who knew the area.

Interviewers were undergraduate students from several colleges and universities who volunteered to conduct the surveys as a service project during their spring break week. Two groups of students participated in the surveying, 1 group per week. Each group received 1 half-day training before the first survey day. The training was led by persons with previous experience conducting similar surveys and by local residents, and consisted of background information on local culture, maintaining personal safety, conflict avoidance, and survey and data recording procedures including practicing mock surveys. 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 participant agreed to be surveyed, the questions were read to the participant and the responses were recorded by the interviewer. On average, the survey took approximately 15 minutes to complete. If more than 1 eligible person was home at the time of the survey, all eligible household residents were invited to take part. Response rate data were collected by recording the result of each household contact: no answer, household declined to participate, or 1 or more residents agreed to be surveyed.

Measures

Survey questions were drawn primarily from preexisting instruments that have been widely used and validated. Most of the survey questions had been used previously by our group and so were well pretested. Items from the Behavioral Risk Factor Surveillance System (BRFSS)[32] were used to record information on self-reported lifetime diagnoses of cancer, heart attack, angina or coronary heart disease, stroke, hypertension, and asthma (including both lifetime and current asthma). A question worded similarly to the BRFSS items was created to assess lifetime diagnosis of "chronic obstructive pulmonary disease (COPD), emphysema, or chronic bronchitis." BRFSS items were also used to record self-reported health status on a 5-point scale (excellent, very good, good, fair, or poor), tobacco use, and age in years. Additional items were prepared for this study including length of time living in their current community, and whether the participant had ever worked as a coal miner. Participant sex was also recorded.

Covariates included questions on smoking, age, sex, time living in the community, occupational exposure as a coal miner, marital status (coded for analysis as married vs any other status), educational attainment (measured on a 6-point scale from "never attended school" to "college 4 years or more"), and height and weight to calculate body mass index (BMI). BMI was used to estimate the presence of overweight or obesity. Persons were grouped into 1 of 3 weight categories: normal (BMI $<$ 25), overweight (BMI 25 to $<$ 30), or obese (BMI $> =$ 30). Most of these items except occupational history and community tenure were from the BRFSS.

Smoking status was measured from BRFSS items as 2 dichotomous 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).

Questions from the National Health Interview Survey family cancer history module[33] were used to determine whether or not a member of the participant's biological family had ever been diagnosed with cancer. Family members included biological mother, father, brothers, sisters, sons, and daughters.

Concerns were expressed by community partners that if we only asked about illnesses occurring among respondents, we would be unable to assess illness or death that may have been experienced by other family members who are unable to respond to the survey. Anecdotally, these family illnesses are commonly reported by residents in mining areas. In response to these concerns, the 3 following Yes/No questions were added to the survey:

- Has anyone in your household had a serious illness within the past year?
- Has anyone in your household died from cancer within the past 5 years?
- Has anyone in your household died within the last year from any cause?

Finally, to measure illness symptoms among respondents, we read a list of 28 symptoms and asked respondents to indicate which of these (if any) they currently have or have had in the past month. This symptom checklist was derived from a medical history exam form used in primary care practice.[34] The 28 symptoms represented 8 categories: respiratory, cardiovascular, skin, gastrointestinal, muscle/joint/bone, neurological, eye/ear/nose and throat, and other (specific symptom items are presented below in Results section). These items were intended to address a wider range of current symptoms than may be captured through the presence or absence of formal diagnoses.

Analysis

A number of household contacts were recorded. The response rate to the survey was calculated as the percent of household contacts with 1 or more completed surveys.

There were 13 primary dependent variables for inferential analysis that assessed the range of health conditions experienced by the participant or household members. Eight of these health outcomes were expressed dichotomously to measure prevalence of self-reported cancer, heart attack, angina or coronary heart disease, stroke, hypertension, COPD, lifetime asthma, and current asthma. In addition, the 5-point item on self-rated health was dichotomized into ratings of excellent/very good/good versus fair/poor (ie, the dependent variable is whether or not the participant rated their own health as fair or poor). Household illnesses were measured using the 3 dichotomous items listed previously.

The 13th health measure was symptoms. Symptoms were dichotomized based on a median split between those with 0 to 4 symptoms versus those with 5 or more symptoms. After analyzing overall symptoms, regression models were then run for each of the 8 symptom categories where the dependent variable was a count of the number of symptoms treated as cumulative logits.

Summaries of variables were calculated and frequencies and means were compared between groups using chi-square or 2-tailed t tests, with significant values set at $P < .05$. Then, each health dependent variable was modeled as a function of mining group (MTM or not) controlling for participant age, sex, education (coded into 2 dichotomous independent variables including high school education, or some college or more, with less than high school as the referent), marital status (married or not), current smoker, former smoker (lifetime nonsmoker as the referent), smokeless tobacco user, overweight, obese (normal weight as the referent), and whether the participant had ever worked as a coal miner. When cancer was the dependent variable, we also added as a covariate a family history of cancer (whether or not 1 or more biological family members had ever been diagnosed with cancer.) SAS software version 9.2 Proc Genmod (SAS Institute Inc., Cary, NC) was used for the modeling, using a robust Poisson distribution for nonrare events.[35] The coefficients from the models were exponentiated to estimate prevalence ratios and corresponding 95% confidence intervals. To gain a sense of the relative magnitude of effects, the prevalence ratios for MTM effects were compared to the prevalence ratios for current smoking and obesity.

Results

Sample Size and Response Rate

There were a total of 952 completed surveys. However, there were missing observations on covariates that reduced the available sample to 895 participants with complete covariate data (94% of the original sample). The most frequently missing item was the question on the participant's weight, missing in 37% or 4% of cases. In an additional set of regression models (results not shown), we coded missing weight as its own category so that these cases could be included in analysis. This had no effect on the significance of any of the mining variables and so we report only models with observed data on BMI. Analyses are reported on the 895 participants, although occasional missing data on outcome measures slightly reduced available samples for specific models. The response rate to the survey was 74% of all household contacts.

Univariate Summary

A descriptive summary of the study covariate data is provided in Table 2. There were 544 participants from the MTM area and 351 from the nonmining area. Participants in the mining area were on average older: 51.8 versus 48.1 years old. Persons in the mining area, on average, were less likely to have college education and more likely to have less than high school education, but the groups did not differ on rates of high school graduates. Persons in the mining area had higher obesity rates (but not higher rates of overweight), and were more likely to be either current or past smokers. Mining area participants were more likely to be currently married than participants from the nonmining area. The groups did not differ on percent female participants or on the percent of smokeless tobacco users. Participants from the mining area were more likely to have had occupational experience as a coal miner. Finally, persons in the mining area had lived, on average, in their community of residence for more years than persons in the nonmining area, an average of 34 years versus 24 years, respectively.

Table 2 Summary of Respondent Characteristics in Mountaintop Mining and Nonmining Communities

	Mountaintop Mining Area (N = 544) N (%)	Nonmining Area (N = 351) N (%)	*P* <
Female	283 (52.0)	185 (52.7)	.84
Married	291 (53.5)	163 (46.4)	.04
Less than high school education	164 (30.2)	47 (13.4)	.0001
High school education	179 (32.9)	104 (29.6)	.31
Some college or more education	201 (37.0)	200 (57.0)	.0001
Current smoker	208 (38.2)	105 (29.9)	.02
Former Smoker	138 (25.4)	69 (19.7)	.05
Smokeless tobacco use	62 (11.4)	36 (10.3)	.60
Family cancer history (one or more family members with cancer)	328 (60.3)	170 (48.4)	.0005
Occupational history as a coal miner	143 (26.3)	20 (5.7)	.0001
Overweight	154 (28.3)	119 (33.9)	.08
Obese	237 (43.4)	106 (30.2)	.0001
	Mean (standard deviation)	Mean (standard deviation)	
Age in years	51.8 (17.7)	48.1 (20.0)	.006
Years living in the community	34.0 (21.4)	24.1 (20.7)	.0001

Table 3 provides a comparison of the health outcomes reported in both locations, before adjusting for covariates. The participants in the mining area reported significantly greater health problems on 11 of the 13 dependent variables. These differences included higher rates of serious household illness and household deaths from cancer. Differences were present on measures of cardiovascular health, respiratory health, self-rated overall health, and high number of illness symptoms. Self-reported cancer rates were not significantly different between the groups.

Adjusted Prevalence Rate Model Results

After adjusting for covariates, participants in the mining area continued to demonstrate significantly higher prevalence rates for 8 of the 13 health measures. These results are shown in Table 4. Significantly higher adjusted prevalence rates were observed for rates of serious household illness, household deaths from cancer, lifetime and current asthma, COPD, hypertension, self-rated overall health, and high number of illness symptoms.

Table 3 Comparison of Health Outcome Measures Between the MTM and Non-mining Groups Prior to Covariate Adjustment

	N	% MTM Area	% Nonmining Area	*P* <
Health of household members				
Serious household illness in last year	891	31.7	17.2	.0001
Household member died of cancer last 5 y	889	15.5	9.5	.01
Household member died from any cause in the last year	885	9.3	8.4	.65
Health of respondent				
Cancer	892	15.3	11.7	.13
Hypertension	881	55.8	37.1	.0001
Angina/coronary heart disease	890	14.4	8.3	.007
Stroke	888	8.3	3.5	.004
Heart attack	888	15.0	9.2	.02
Lifetime asthma	892	22.3	12.6	.0002
Current asthma	886	18.2	8.3	.0001
COPD	865	25.9	7.5	.0001
Self-rated health fair or poor	893	49.4	27.1	.0001
Five or more current symptoms	895	50.0	27.9	.0001

Table 4 Prevalence Ratios and 95% Confidence Intervals (PR and 95% CI) for Health Outcomes in the Mountaintop Mining Group Compared to the Nonmining Referent, Controlling for Covariates:[a] Prevalence Ratios for Current Smoking and Obesity Are Shown for Comparison

	Mountaintop Mining PR (95% CI)	Current Smoking PR (95% CI)	Obesity PR (95% CI)
Health of household members			
Serious household illness in last year	1.67 (1.27–2.20)	0.96 (0.73–1.27)	1.03 (0.80–1.34)
Household member died of cancer last 5 y	1.54 (1.04–2.26)	1.24 (0.82–1.88)	1.36 (0.91–2.02)
Household member died from any cause in the last year	1.09 (0.69–1.73)	1.00 (0.59–1.68)	1.07 (0.65–1.73)
Health of respondent			
Cancer	1.13 (0.79–1.60)	1.48 (0.97–2.26)	0.77 (0.52–1.14)
Hypertension	1.30 (1.12–1.51)	1.15 (0.98–1.35)	1.54 (1.31–1.81)
Angina/coronary heart disease	1.31 (0.85–2.01)	2.12 (1.30–3.44)	1.59 (1.04–2.41)
Stroke	1.68 (0.89–3.19)	1.75 (0.60–0.93)	1.55 (0.87–2.78)
Heart attack	1.03 (0.69–1.53)	1.88 (1.18–2.99)	1.44 (0.99–2.10)
Lifetime asthma	1.56 (1.11–2.19)	1.17 (0.82–1.67)	1.00 (0.73–1.38)
Current asthma	1.68 (1.11–2.54)	1.37 (0.90–2.08)	1.20 (0.83–1.74)
COPD	2.47 (1.62–3.74)	2.54 (1.73–3.72)	1.11 (0.81–1.51)
Self-rated health fair or poor	1.40 (1.16–1.70)	1.42 (1.17–1.71)	1.34 (1.12–1.60)
Five or more current symptoms	1.54 (1.28–1.87)	1.49 (1.22–1.81)	1.29 (1.08–1.55)

[a]Covariates include: age, sex, college education, high school education, marital status, occupational experience as a coal miner, overweight, obesity, current smoker, former smoker, and smokeless tobacco use. Family history of cancer is used as a covariate in the cancer model.

After observing the significant difference in the prevalence of high numbers of symptoms in the mining group, an additional set of adjusted prevalence rate analyses was conducted to examine which types of symptoms might be more common by estimating models for each of the 8 symptom types. Persons in MTM areas had significantly higher symptoms in all 8 areas after controlling for other risks. These results are summarized in Table 5 and show the 28 individual symptoms that were used to measure each of the 8 symptom categories. Analyses were then conducted for each of the 28 individual symptoms (results not shown): adjusting for covariates, participants in MTM areas reported significantly higher risks for 21 of the 28 symptoms (all significant at $P < .05$ although gall bladder symptoms were marginally significant at $P = .052$.) All symptoms were significantly higher in the MTM group *except* irregular or rapid heartbeat, skin lesions, vision flashes or halos, hearing loss, ringing in ears, throat pain or difficulty swallowing, and fever.

In comparing the size of the prevalence ratios for MTM to the size of the prevalence ratios for current smoking or obesity, results show that MTM effects were of comparable or larger magnitude for many of the effects (see Tables 4 and 5). MTM effects were comparable or larger than smoking for current and lifetime asthma, COPD, hypertension, fair/poor health, measures of household

Table 5 Prevalence Ratios and 95% Confidence Intervals (PR and 95% CI) for Presence of Symptoms in the Mountaintop Mining Group Compared to the Nonmining Referent, Controlling for Covariates;[a] Prevalence Ratios for Current Smoking and Obesity Are Shown for Comparison

	Mountaintop Mining PR (95% CI)	Current Smoking PR (95% CI)	Obesity PR (95% CI)
Symptom Group			
Respiratory (3 items: persistent cough, shortness of breath, wheezing)	1.71 (1.35–2.15)	2.67 (2.10–3.40)	1.32 (1.07–1.66)
Cardiovascular (2 items: chest pain, irregular or rapid heartbeat)	1.44 (1.10–1.88)	1.62 (1.23–2.13)	1.40 (1.07–1.82)
Skin (2 items: itches or rashes, skin lesions)	1.69 (1.12–2.55)	1.13 (0.70–1.83)	1.08 (0.72–1.63)
Gastrointestinal (5 items: stomach or abdominal pain, nausea, constipation or diarrhea, vomiting, gall bladder problems)	1.67 (1.33–2.08)	1.13 (0.89–1.44)	1.30 (1.04–1.63)
Muscle/joint/bone (1 item: pain, weakness, swelling or numbness in arms, legs, hands, feet or back)	1.42 (1.18–1.72)	1.32 (1.09–1.60)	1.37 (1.14–1.66)
Neurological (4 items: dizziness or fainting, headache or migraines, seizures, shaking or tremors)	1.60 (1.30–1.96)	1.16 (0.92–1.45)	1.14 (0.92–1.41)
Eye, ear, nose and throat (7 items: blurred or double vision, flashes or halos in vision, hearing loss, earache or ear discharge, ringing in ears, throat pain or difficulty swallowing)	1.30 (1.11–1.52)	1.18 (0.98–1.42)	1.17 (0.98–1.40)
Others (4 items: chills, fever, fatigue, painful urination)	2.09 (1.56–2.81)	1.34 (0.95–1.82)	0.97 (0.75–1.27)

[a]Covariates include: age, sex, college education, high school education, marital status, occupational experience as a coal miner, overweight, obesity, current smoker, former smoker, and smokeless tobacco use.

illness and household cancer deaths, and all symptom groups except respiratory. MTM effects were comparable or larger than obesity effects for lifetime and current asthma, COPD, fair/poor health, measures of household illness and household cancer deaths, and all 8 symptom groups.

Discussion

The results show that adults residing in an area of eastern Kentucky characterized by mountaintop coal mining have elevated prevalence rates for multiple types of health problems compared to a nonmining area, after statistical control for other risks. These health problems include poorer self-rated health, lifetime and current asthma, COPD, hypertension, and a wide set of current or recent illness symptoms representing multiple-organ systems. In addition, residents of the MTM area reported that members of their household had experienced higher rates of serious illness and had higher death rates from cancer in the past 5 years.

Two outcomes that have been documented in previous studies in MTM areas were not replicated in this study. These include self-reported cancer and cardiovascular disease diagnoses. In the case of cancer, we make 2 observations. First, rates of *household* death from cancer were significantly higher in the MTM group. Second, the percent of lifetime cancer in the MTM group reported in this study (15.3%) was similar to the 14.4% reported in the West Virginia survey study,[29] but the percent reported in the Kentucky control group (11.7%) was higher than the West Virginia control group (9.4%). That is, we may have detected an unusually high percent in the Kentucky control group, either by chance or as a result of other unknown risks in the control group. Several other studies have documented higher cancer in Appalachian mining areas[10,29,36,37] such that the current results are a deviation from prevailing evidence.

Similarly, we did not find higher rates of coronary heart disease or heart attack in this study although these effects have been found in previous research on coal mining communities.[8-40] These cardiovascular conditions were more prevalent in the MTM group before adjusting for covariates, but after adjustment were no longer significant (in particular, greater age, male sex, smoking, and lack of college education were most strongly related to these outcomes.) We note that hypertension and chest pain, an important cardiovascular health symptom, were significantly higher in the MTM group after adjusting for other risks. Reasons for the current results are unknown but may reflect insufficient statistical power, higher risks in the control group, higher cardiovascular disease mortality in the mining group that precludes their ability to report on disease, or that cardiovascular disease does not occur at higher adjusted rates in this particular mining area.

A new contribution of this study over previous research on this topic is the information collected regarding the health of household members. Respondents reported that members of their household were at increased risk for serious illness or death from cancer. The cancer finding for household members is in contrast to the nonsignificant difference in self-reported cancer survivorship and suggests that cancer mortality may be more severe in the MTM area such that survivors are not present in the household to report on their cancer status.

Results also show that residents of the MTM community reported more prevalent illness symptoms across a wide range of organ systems. The symptoms reported more commonly in the MTM community included chest pain, persistent cough, wheezing, skin rashes, stomach and abdominal pain, gall bladder problems, pain in muscles or joints, headaches, fatigue, and others. On the one hand, if there are environmental exposures taking place in these areas, it may seem surprising that health effects could be so widespread as opposed to more focused symptoms resulting from exposure to a particular agent. However, early environmental evidence indicates that there is not a single agent or transport route that characterizes these mining environments, but rather that multiple exposure types may be occurring that could impact different people in different ways.

This early environmental evidence shows higher levels of respirable dust in MTM versus nonmining control sites, and higher estimates of deposition or dose of particulate matter into the lung.[22,41] The dust includes organic compounds that are not present in control sites.[22] Elemental and organic analyses indicate that MTM dust is primarily organic carbon (the coal itself) and silica, followed by sulfur, aluminum, and other rare earth elements that originate from the overburden—the rock and soil above the coal seams—that is released into the environment by explosives and machinery during extraction activities. Silica is highly toxic; when inhaled it results in inflammatory responses and is linked to lung disease and cancer.[42-45] Water samples from MTM communities include substantially elevated conductivity and pH, elevated ammonium and phosphate concentrations, and elevated polycyclic aromatic hydrocarbons and phenols;[45] these may originate from coal processing activities or the use of explosives at mining sites. Ground water from domestic wells has in some cases possibly become contaminated from mining activity or coal cleaning processes.[20,46,47]

The use of student volunteers to conduct the surveys offers strengths and potential limitations to the study. Students were highly motivated, positive, and energetic. They were also highly receptive to instructions as to survey protocol and the importance of obtaining accurate information. Most of the volunteers were female and were from small Christian colleges, and qualitatively, it seemed that local residents were at ease and welcoming of the volunteers. However, beyond the half-day training and the debriefing sessions, students were not observed or tested for accuracy during the actual surveying, which may lead to possible inaccuracies in recording survey responses. Effects of possible inaccuracies would appear to be minimal given the structured nature of the survey instrument, and the use of the same survey procedures in both mining and nonmining areas.

The study is limited by the ecological design; we know that participants live in counties characterized by the presence or absence of MTM, and we know that residential communities proximate to mining are higher in water and air contaminants, but we have no direct measures of environmental exposures among participants. A second study limitation relates to survey sampling procedures. Contact attempts at most households occurred only once, and most survey activity was conducted during weekday hours (although limited evening and weekend hours were included) because of the logistical and cost difficulties involved in transporting and housing the student volunteers. This could result in survey respondents in both locations who 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 health problems in one area relative to another. Third, reports of family members' health experiences may suffer from recall bias, although it seems unlikely that this would differentially affect the mining or nonmining samples. Fourth, the 2 nonmining counties were different demographically from each other, particularly in that 1 county (Rowan) is home to a small university and its population has higher levels of college education. We included education level as a covariate but there still might be some unique features of this population that make it different from the others. Finally, asking people if they have ever had cancer, respiratory disease or cardiovascular disease limits the collection of this information to survivors. If there are differences between the groups in access to medical care, stage at diagnosis, or medical complications that increase mortality risk, that could result in differential survivorship and an underreporting in the group with worse care or more serious illness. It is unclear whether 1 group or the other may be at increased risk for poorer medical care, although the MTM group had greater experience of household cancer mortality and a greater number of illness symptoms, suggesting that illness severity is higher in the MTM group.

Conclusion

The results of this study add to previous evidence that Appalachian health disparities are concentrated in mountaintop coal mining areas of the region. The precautionary principle of environmental science dictates that prudent steps be undertaken to minimize and eliminate risks from possible exposure.[48] As has been previously recommended based on the environmental and public health evidence,[18] one of these steps is that MTM practices should end. Absent that, regulations governing both air and water quality in impacted communities may be strengthened. Air quality standards should pay particular attention to the levels of ultrafine particulate matter (PM $< 0.1\mu$m) coming from mining activities, as evidence suggests that ultrafine levels in mining communities are especially pronounced.[41]

In addition to environmental protections, there is a need for new investments in these impacted communities so that better economic and physical environments can be created as mining activity becomes historical. Many central Appalachian areas are medically underserved, and better public health and health care services would help to address health disparities. Investments in improved infrastructures, such as better access to high-quality food sources, would also help to address public health problems. Increases in coal taxes or redistribution of existing taxes could be directed specifically to postcoal economic development in coalfield communities. The national goal to eliminate Appalachian health disparities will not be achieved unless disparities are eliminated in MTM areas, and that means not simply ending mountaintop removal, but creating better economic opportunities and environmental conditions in these disadvantaged communities.

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