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Residence in Coal-Mining Areas and Low-Birth-Weight Outcomes

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Abstract The objective of this study was to estimate the association between residence in coal mining environments and low birth weight. We conducted a cross-sectional, retrospective analysis of the association between low birth weight and mother's residence in coal mining areas in West Virginia. Birth data were obtained from the West Virginia Birthscore Dataset, 2005–2007 ($n = 42{,}770$). Data on coal mining were from the US Department of Energy. Covariates regarding mothers' demographics, behaviors, and insurance coverage were included. We used nested logistic regression (SUDAAN Proc Multilog) to conduct the study. Mothers who were older, unmarried, less educated, smoked, did not receive prenatal care, were on Medicaid, and had recorded medical risks had a greater risk of low birth weight. After controlling for covariates, residence in coal mining areas of West Virginia posed an independent risk of low birth weight. Odds ratios for both unadjusted and adjusted findings suggest a dose-response effect. Adjusted findings show that living in areas with high levels of coal mining elevates the odds of a low-birth-weight infant by 16%, and by 14% in areas with lower mining levels, relative to counties with no coal mining. After covariate adjustment, the persistence of a mining effect on low-birth-weight outcomes suggests an environmental effect resulting from pollution from mining activities. Air and water quality assessments have been largely missing from mining communities, but the need for them is indicated by these findings.

Keywords Low birth weight · Coal mining · Environmental · Coal toxicity

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Residence in a coal mining area serves as an indicator of environmental contamination from the mining industry. The environment profoundly influences the genetic constitution of newborns and impacts transplacental exposure that negatively affects birth outcomes. Specifically, molecular studies have documented significant transplacental transfer of contaminants, including polycyclic aromatic hydrocarbons (PAHs) and environmental tobacco [1, 2]. In addition, the fetus may be vulnerable to pollution stored inside the mother's body [3].

Low birth weight, defined as less than 2,500 g, occurs in 5–8% of births in the United States including 2% of term births [4]. Studies show that low-birth-weight outcomes are associated with exposure to the following toxicants: lead [5, 6]; ambient air pollutants [7–12]; air pollution associated with sulfur dioxide, nitrous dioxide and/or carbon monoxide [11, 13, 14]; traffic particulates [12]; well-water nitrate level [15]; and environmental tobacco smoke [16–21]. In addition, one study shows an association between reduced birth weight and exposure to inorganic arsenic [22]. In a recent literature review, Wigle et al. [23] concluded that there is sufficient evidence that prenatal active smoking is significantly associated with low-birth-weight outcomes, and limited evidence of such an association for lead, some pesticides, environmental tobacco smoke, outdoor air

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pollution, and drinking water disinfection by-products and nitrate.

Environmental contamination can occur through a variety of locations and mediums. Accumulating evidence indicates that coal mining and processing areas are associated with significant environmental toxicity. Coal mining deposits or releases toxic chemicals into local environments, including PAHs, arsenic, mercury, lead, cadmium, selenium, nickel, and copper [24, 25]. Coal processing involves use of toxic chemicals, as well as equipment powered by diesel engines, explosives used in mining, dust from uncovered coal trucks and trains, and dust from unpaved haul roads, all of which cause environmental pollution. The materials rejected by a cleaning plant tend to be enriched in iron sulfides (e.g., pyrite and marcasite). These oxidize easily into sulfates, causing the acidification of any water that percolates through and exits from refuse piles. Acid water in turn tends to dissolve various other minerals, creating products that are potentially harmful to plants, animals, and humans.

Evidence shows that coal processing contaminates billions of gallons of water with toxic trace elements and chemical compounds used in the coal preparation process [25, 26]. Contaminated water is held in impoundment ponds, or injected underground where interface with drinking water sources may occur. Ambient particulate matter (PM_{10} and $PM_{2.5}$), sulfur dioxide, and nitrous oxide are elevated in areas proximate to coal extraction, processing, and transportation [27, 28]. In a 2004 study, half of 179 samples from private wells in coal-mining areas of Appalachia had detectable arsenic [29]. Elevated levels of iron, manganese, aluminum, lead, and arsenic have been shown in ground water in mining vs. non-mining areas of Appalachia [30, 31].

Importantly, surface mining as a percentage of total mining and as absolute production figures has been increasing in the United States [32]. In West Virginia, a form of surface mining referred to as mountaintop removal mining relies on surface explosives and removal of up to 1,000 feet of rock and soil above the coal seams [33]. Levels of particulates are higher in surface mining vs. underground mining operations and result in exposure at a community, rather than miner-only, level [28, 34]. Recent evidence shows that higher mortality rates and higher rates of self-reported chronic illness among adults in coal mining areas are significantly related to age, poverty, education, smoking, and lack of health insurance; however, after controlling for these effects, the relationship between morbidity and mortality rates and residence in a coal-mining area remained significant [35–37]. These effects are population-wide for both men and women, suggesting that these effects are not limited to occupational exposure among coal miners [35–37].

Previous research on community health effects of coal mining has been limited to studies of adult health. However, given what is known about environmental toxicants and birth outcomes, a relationship between coal mining and low birth weight may also be expected. This study tests the hypothesis that pregnant mothers who live in coal mining areas will be at greater risk for low birth weight outcomes than mothers in non-mining areas after adjustment for other risk factors.

Methods

Data

Birth data were obtained from the West Virginia Birthscore Dataset [38], which includes records for all live births and is based primarily on the variables in the state's birth certificate record [39]. It includes variables describing the mother (e.g., age, smoking and drinking during pregnancy, number of previous pregnancies), the birth event (e.g., labor and delivery complications), and the child (e.g., birth weight, weeks gestation). Data on coal mining were taken from the Department of Energy, Energy Information Administration (EIA). Data included were the tons of coal mined in each West Virginia county for each year 2005–2007.

Design

The study is a cross-sectional, retrospective analysis of the association between low birth weight and mother's residence in coal mining areas of the state, before and after control for covariates.

Variables

The dependent variable of interest is birth weight. Birth weight in grams is recorded in the dataset and was converted to a dichotomous measure of low birth weight (yes/no) based on whether birth weight was less than 2,500 g. The primary independent variable of interest is residence in a county with a zero, moderate, or high level of coal mining. Counties with coal mining were divided into levels of coal tonnage: none, moderate, and high. High and moderate levels were based on a median split of total production over the years 2005 through 2007. The split occurred at 13,510,500 tons of coal.

Covariates were obtained from the Birthscore Dataset. The mother's age was converted to a categorical variable (less than 18, 18–39, 40 and above) to capture risks of low birth weight for mothers who are younger or older. Dichotomous variables measured whether the mother smoked or drank alcohol during the pregnancy based on self-report. Marital status (married or not) was recorded, as were years of education, based again on the mother's self-report. The first month of prenatal care was coded into dichotomous variables representing early (first trimester, yes or no), late (second/third trimester, yes or no) or no prenatal care. Number of previous pregnancies was recorded, which included live births, abortions and stillbirths. Insurance coverage was grouped into Medicaid, uninsured, or private insurance. A text field on the dataset recorded the presence of a wide range of medical risks experienced by the mother, including, for example, gestational diabetes and drug addiction. For the current study, these medical risks were simply coded as the presence or absence of any recorded medical risk in the dataset.

Validity and Reliability of Data

Regarding the validity and accuracy of the birth data, birth weight is recorded by medical personnel in grams and can thus be considered accurate. In addition, mother's age, information about the birth event (e.g., labor and delivery complications), and the child's birth weight and weeks gestation are all variables that are observed by medical personnel and recorded, and can be considered as reliable. In contrast, self-reported variables, including smoking and drinking during pregnancy, number of previous pregnancies, marital status, drug addiction, and years of education, may not be as accurate as variables recorded by medical personnel. In particular, self-reported smoking, drinking, drug-use, and previous pregnancies are likely to be understated. However, there is no reason to believe such understatement would be more severe or less severe in mining areas.

Data Analysis

The data for this study were anonymous, and the study met the University's standards for exemption from the IRB process. The total number of live births in West Virginia for the years 2005–2007 was 45,008. Missing data on study variables reduced the sample available for analysis to 42,770 (a loss of less than 5% of cases). Descriptive analysis of all variables was first undertaken. Subsequently, inferential analyses were undertaken which employed SUDAAN Proc Multilog models to account for the complex design of individual level observations nested within county-level coal production categories. Counties with no mining served as the referent. Mothers who received early prenatal care served as the referent relative to late or no prenatal care. Medicaid coverage and no insurance coverage were included as two dummy variables with private insurance as the referent.

Results

As shown in Table 1, for mothers residing in mining areas, there is a significant association between receiving late prenatal care and elevated risks for low birth weight outcomes. As shown in Table 2, mothers in mining areas have a significantly higher risk of low birth weight before controlling for covariates. Further, there is evidence of a dose-response effect as the odds ratio (OR) is higher in areas of higher levels of mining compared to areas of moderate mining levels.

Table 3 shows results after controlling for covariates. The risk of low birth weight is related to previously established factors as expected (Table 3). In particular, mothers

Table 1 Summary of study variables

	No. coal mining	Moderate mining up to 13,510,500 tons	High mining 13,510,500 tons or more	Total
N	15,788	7,833	19,149	42,770
% LBW*	8.5	9.6	9.9	9.3
Mother's characteristics				
% age <18*	4.0	3.9	3.3	3.7
% age >39	1.3	1.4	1.5	1.4
% married*	59.3	60.2	61.5	60.5
% drink during pregnancy	0.4	0.4	0.4	0.4
% smoke during pregnancy*	26.4	31.3	27.8	27.9
% with medical risk*	26.2	20.8	29.5	26.7
% with late prenatal care*	13.5	16.3	17.8	15.9
% with no prenatal care	0.41	0.40	0.60	0.50
Mean years education**	12.9	12.6	13.0	12.9 (2.3)
Mean number of previous pregnancies (SD)	1.32	1.29	1.30	1.30 (1.4)

* Chi-square < .01

** *F* test < .01

Table 2 Summary of coal mining association with low birth weight risk, before covariate adjustment

	No. coal mining (referent)	Moderate mining	High mining
LBW odds ratio:	1.00	1.14 (1.04 1.25)	1.18 (1.10, 1.27)

Cells include odds ratio and 95% confidence interval

Model Satterthwaite adjusted chi-square = 19,749, $df = 3$, $P < .0001$

Table 3 Summary of coal mining association with low birth weight risk, including covariate adjustment

	OR (95% CI)	$P<$
Independent variable		
High coal mining	1.16 (1.08, 1.25)	.0002
Moderate coal mining	1.14 (1.04, 1.25)	.0033
No coal mining (referent)	–	
Mother's age <18	1.03 (0.87, 1.22)	.80
Mother's age >39	1.44 (1.13, 1.85)	.003
Married	0.92 (0.86, 0.99)	.007
Drink during pregnancy	1.29 (0.84, 1.97)	.18
Smoke during pregnancy	1.88 (1.75, 2.02)	.00001
Medical risk	2.19 (2.05, 2.34)	.00001
Years education	0.96 (0.95, 0.98)	.00001
Late prenatal care	1.01 (0.93, 1.11)	.75
No prenatal care	1.79 (1.31, 2.46)	.0002
Number of previous pregnancies	0.98 (0.95, 1.00)	.22

Cells include odd ratios and 95% confidence intervals

Model Satterthwaite adjusted chi-square = 18,058, $df = 13$, $P < .0001$

who smoke, who did not receive prenatal care, who were on Medicaid, and who had recorded medical risks had a greater risk of low birth weight. Other risks include mothers who are older, unmarried, and less educated.

After controlling for these risks, areas of the state with either lower or higher levels of coal mining pose an additional independent risk (Table 3). The odds ratios for both unadjusted and adjusted findings suggest a dose response effect because they are highest for higher levels of mining compared to lower mining levels. Before adjustment, living in a high coal mining area increased the odds of a low-birth-weight infant by 19%; after adjustment, the odds were still elevated by 16%. For areas with lower mining levels, the odds of a low-birth-weight infant were increased by 13% before adjustment and 14% after adjustment.

Discussion

This study finds a significant association between residence in coal mining areas and the risk of a low-birth-weight outcome, after controlling for the mother's age, marital status, education, prenatal care, number of previous pregnancies, drinking and smoking behaviors, insurance coverage, and existence of medical risks. This additional risk for low-birth weight outcomes is not surprising, as proximity in coal mining counties means proximity to environmental contaminants associated with coal mining, cleaning and transport. Studies show that environmental risks in the form of air and water contamination are associated with coal mining activities, including the release of lead, arsenic, mercury, sulfur, cadmium, beryllium [40], and elevated levels of air particulates [41].

Of particular interest is the area of research examining the relationship between air particulates and fetal development. Recent studies have increasingly examined the impact of polycyclic aromatic hydrocarbons and fine particles on pregnancy outcomes, and found support for the idea that adverse pregnancy outcomes may result from maternal exposures to airborne pollution [42–46]. One recent study of the impact of PAHs on fetal development, conducted in a highly polluted area, found a significant relationship between maternal exposure to fine particles during early gestation and intrauterine growth retardation [47]. However, the study was not able to differentiate the impact of the particulates themselves, vs. the impact of co-pollutants carried by the particles. Further research is needed to differentiate impacts of air particulates vs. co-pollutants carried by particulates in coal mining areas.

Importantly, mountaintop removal mining poses unique environmental risks, including significant air particulate exposure. Mountaintop removal mining has increased in West Virginia from 19 to 42% between 1982 and 2005, and continues to increase [48]. This type of mining enables quicker access to coal with lower labor costs, but intensifies environmental degradation. The EPA estimates that between 1985 and 2001, 724 miles of Appalachian streams were permanently destroyed, and 4 million acres will ultimately be impacted by mountaintop removal mining [49]. Growth in mountain-top removal mining means that entire communities are exposed to polluting methods of mining and processing, rather than being limited primarily to those who are coal-miners.

Limitations of the study include crude coding of medical risks. Future research needs to refine categories of medical risks to understand the contribution of each of these risks on low birth weight outcomes. In addition, the level of coal mining served as an environmental proxy for air and water contamination, as no direct environmental data related to levels of air particulates or types of water contamination in each of these areas were available. An additional limitation relates to self-reported data. In particular, the percent of mothers who drank during pregnancy, for example, may be underreported. Finally, smoking is only measured dichotomously.

As the population grows and oil prices rise, coal is increasingly being mined. Between 1996 and 2005, coal production in the United States increased by 67 million tons [50, 51]. Over 90% of national mercury and sulfur dioxide emissions for electricity generation comes from coal [52]. Follow-up studies of children born with extremely low birth weights show that they fare worse than children with normal birth weights in almost every type of assessment (neurosensory, IQ, chronic conditions, functional limitations, etc.) [53, 54], putting children born in coal mining areas at a disadvantage. This impact may continue into adulthood, as adults who were low-birth-weight infants have more chronic diseases, including hypertension, diabetes mellitus, and obesity [55]. As coal production grows, associated toxicity is increasing. It is important to recognize that environmental pollutants from coal production are controllable pollutants that need to be minimized and eliminated to ensure fetal health.

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