Prevalence Rates of Adult Obesity and Environmental Factors Impacting Health in Coal Producing and Non-Coal Producing Appalachian Counties in Southwest Virginia

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ABSTRACT

Recent publications have stirred controversy by associating mountain top coal mining in Appalachia with elevated prevalence rates of chronic health conditions, including obesity. Obesity is a known comorbidity and precursor for various chronic health conditions: cardiovascular diseases, hypertension and diabetes mellitus, etc. Prevalence rates of obesity have persisted and increased over time in the United States, particularly in rural and underserved areas, including southwest Virginia counties. Identifying environmental factors contributing to obesity may guide future interventions designed to improve health rather than associating mountain top mining as the environmental factor impacting chronic health. The primary objective of the current study was to evaluate the prevalence rates of adult obesity in coal producing and non-coal producing counties in southwestern Virginia. The secondary objective was to compare in both geographic areas environmental factors known to contribute to elevated obesity rates. Identifying modifiable factors affecting obesity rates would provide reasonable guidance for future health intervention programs to reduce obesity and improve comorbidities in this region of Central Appalachian.

Measures of environmental factors were statistically similar in coal and non-coal counties, i.e., percentages of adult obesity, smoking, income, poverty, unemployment, health care costs, insurance coverage, rurality and ethnicity. Significant differences revealed coal counties compared to non-coal counties had a lower percentage of the population over 65 years of age (17.1 ± 1.7 vs. 19.8 ± 1.3; $p < 0.05$), a lower high school completion percentage (73.0 ± 4.7 vs. 78.3 ± 4.2; $p < 0.05$) and a higher number of deaths due to injury (109 ± 22.4 vs 83 ± 15.5; $p < 0.05$). An inverse correlation coefficient was reported for obesity and death due to injury ($r = -0.76$; $p = 0.03$). Other correlations indicated strong

positive relationships, i.e., with coal production and percent of the population smoking ($r = 0.79$; $p = 0.04$). To conclude, coal producing counties did not differ from non-coal producing counties based on most current measures of environmental factors. The exceptions were the lower percentages of high school graduates, the higher number of deaths per county due to injury, and a lower percentage of individuals aged 65 and older in coal counties compared to non-coal counties. Further study delineating a biochemical mechanism is needed if a true cause-effect relationship is to be confirmed between coal production and health related factors.

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INTRODUCTION

Obesity is a major problem affecting adults and children in the United States (US). Over the past 50 years the prevalence of obesity in US adults aged 20 years and over has increased from 13.4 percent (1960-1962) to 35.1 percent (2011-2012) (CDC 2011; May et al. 2013; Ogden et al. 2014). Consequently, a growing concern is that obesity, considered a disease, is a comorbidity with other chronic diseases, including coronary artery disease, Type 2 diabetes mellitus, various cancers (endometrial, breast, and colon), hypertension and stroke. Obesity is affected by genetics, metabolic processes, education, our urban environment, behavioral choices, socioeconomic status and education. A variety of environmental factors and health behaviors have long been known to contribute to obesity and associated comorbidities, most notably poor diet, physical inactivity, availability of processed and fast food, lack of fresh food, lack of access to care, lower health literacy, poverty, unemployment, and lower educational attainment. The most comprehensive national study of factors that influence health, *County Health Rankings and Road Maps Reports,* has been conducted and released annually by the Robert Wood Johnson Foundation (RWJF) since 2010. This report of county level data draws attention to health behaviors, social and economic factors and demographic indicators. Additional measures of clinical care and the physical environment add context to the environmental setting that influences health (RWJF 2015).

Health disparities often parallel economic disparities, which are particularly poignant in Virginia (VA). In 2015, six of the top 25 wealthiest counties in the US were in northern VA (Figure 1, Forbes 2015). At the other end of the spectrum, 25 of the state's 131 counties (including cities considered county equivalents) were included in the Appalachian Regional Commission's (ARC) territory with most classified as economically distressed or 'at-risk'. The three factors used by the ARC to determine economically distressed counties were unemployment rate, per capita income and 3-year poverty rate, all relative to national rates (ARC 2015). Many of these counties also have higher than average adult obesity rates (Figure 2, VDH 2013).

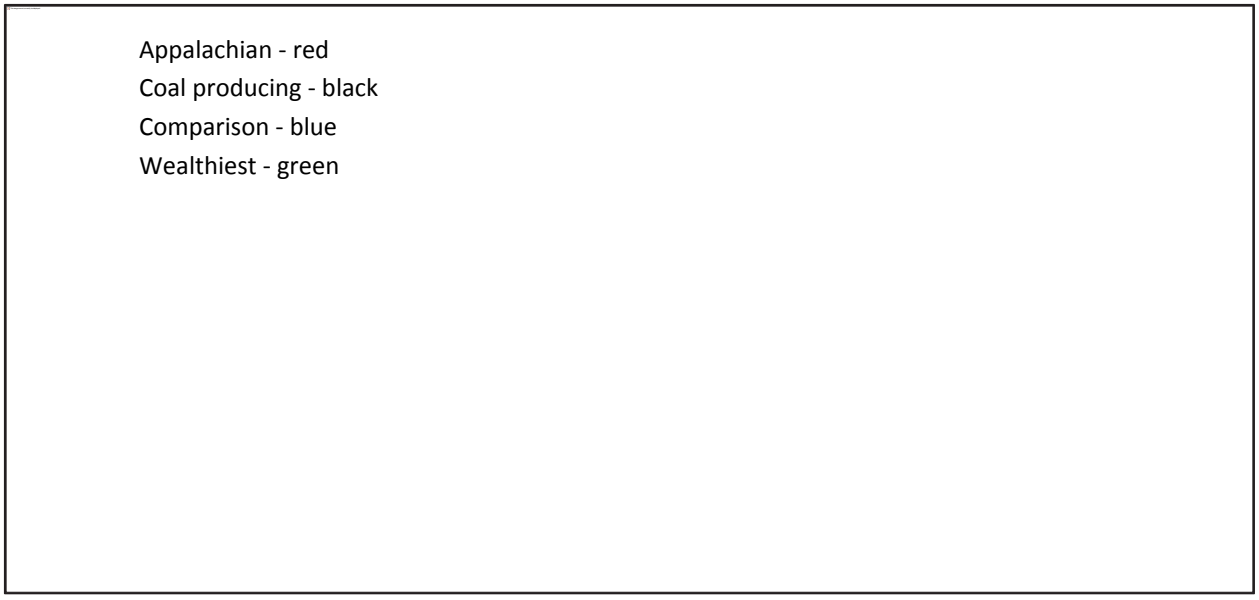

Figure 1. Virginia counties that were in Appalachia (n=25, red), coal producing counties in southwest Virginia (n=7, black), southwest Virginia counties demographically and geographically similar (n=11, blue) and VA counties among the top wealthiest counties in the U.S. (n=6, green) (Sources: EIA, 2014; ARC, 2014; and Forbes, 2015)

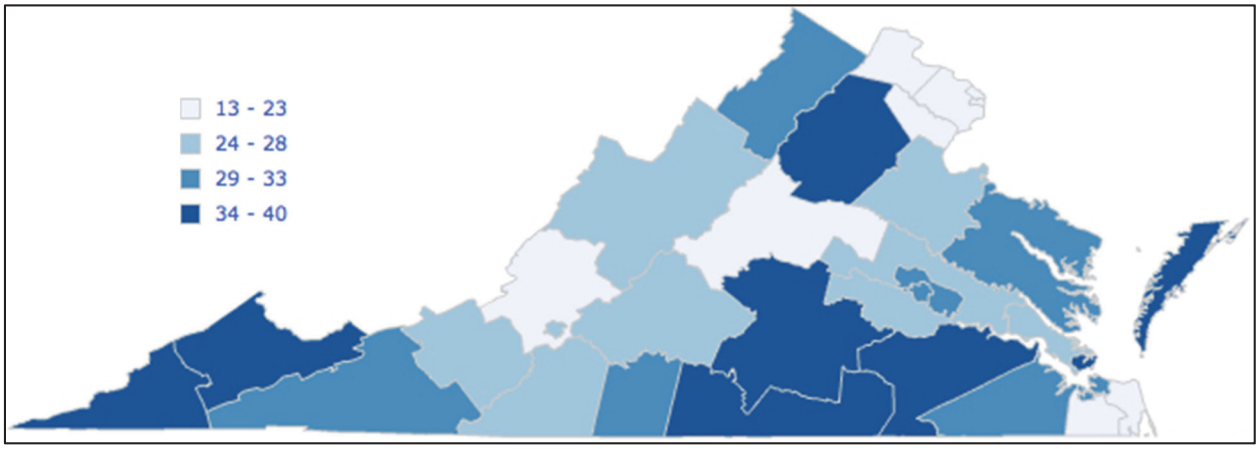

Figure 2. Virginia health districts percent of adults who are obese (BMI ≥ 30) from 2007 to 2009. Coal producing counties in southwest Virginia have the highest BMI indices; 34 to 40 percent (VDH)

Virginia's only coal producing counties are in its southwest region and are predominantly rural and heavily dependent economically on this industry (Figure 3, EIA 2013). One-third of coal production is from surface mining operations including mountain top removal (MTR). From 2011 to 2012, VA coal production declined 16 percent, average sales price decreased by 19 percent, and employment dropped five percent in all mining operations (EIA 2015). These economic and employment hardships add to the existing burden of chronic disease. With job loss comes the loss of employer paid health benefits for the employee and family while a reduced income prohibits paying for care and health insurance.

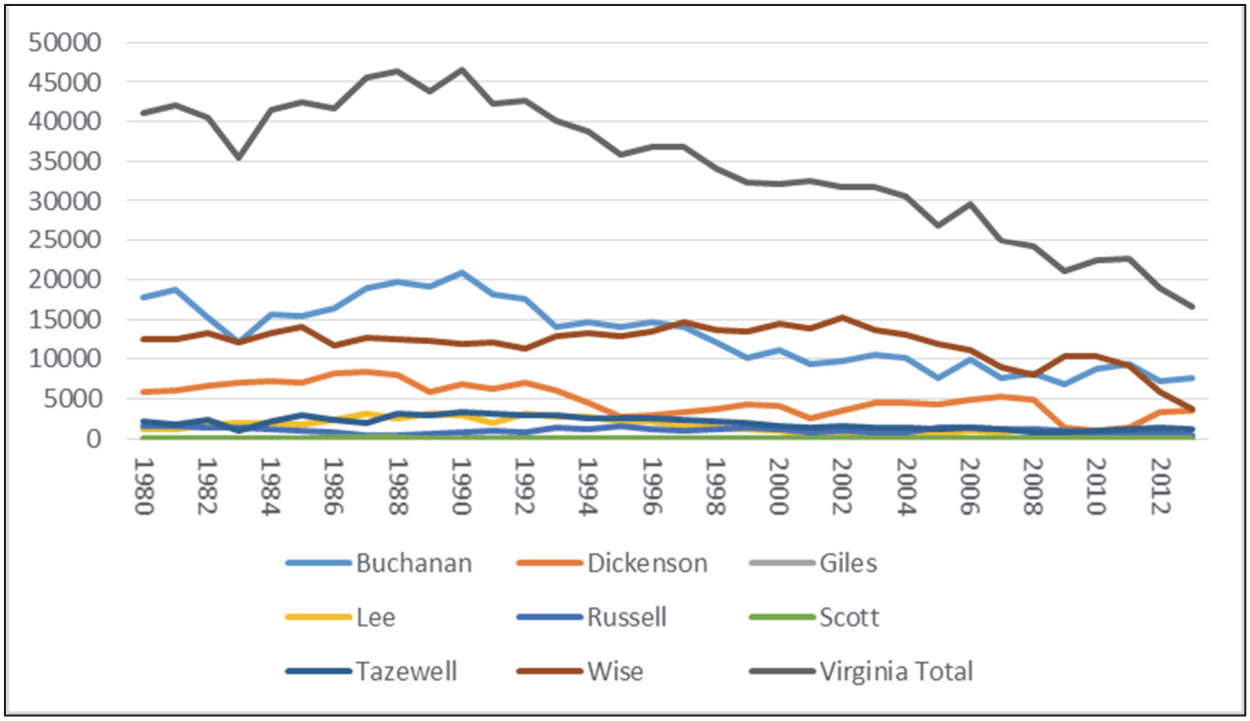

Figure 3. Total coal production in southwest Virginia counties in 1,000 short tons/county/year from 1980-2013. Southwest Virginia counties produced almost 100 percent of the state's total coal production from 1980-2013

There are those who have proclaimed that the environmental effects of MTR are responsible for continued health disparities in coal mining regions of Appalachia. Michael Hendryx and coauthors have published dozens of journal articles relating coal mining activities to higher rates of cardiovascular, hypertension, cancer, diabetes, obesity and even birth defects. Independent researchers and reassessment of publicly available data have produced conflicting results regarding the impact of coal production on chronic disease rates. Our previous literature review assessed research quality, publication quality and author associations and concluded that methodology concerns in previous studies weakened evidence relating coal mining activities to community chronic disease prevalence (Meacham et al. 2012, 2013; Woolley et al. 2015).

The following study was conducted comparing obesity prevalence rates and environmental factors known to affect obesity and comorbidities in coal and non-coal producing counties in the geographically-specific area of southwest VA.

METHODS

Total annual coal production in 2012, including both underground and surface operations, reported in thousands of short tons was obtained from the Energy Information Agency (EIA) for the following seven VA counties: Buchanan, Dickenson, Lee, Russell, Giles, Tazewell, and Wise. The coal producing counties were in the most southwestern health districts in VA. Neighboring southwest VA non-coal producing counties were selected for comparison: Bland, Carroll, Grayson, Scott, Smyth, Washington and Wythe. These fourteen counties were geographically, demographically, and economically similar. Data on factors known to influence the health of a county were obtained from the *County Health Rankings and*

Road Maps (RWJF 2014) and the ARC (2014). Coal production was obtained from the US Department of Labor, Mine Safety and Health Administration (EIA 2014).

More than 15 health factors reported at the county level were selected on the basis of their known impact and/or influence on obesity, defined as the percentage of the adult population (age 20 and older) that has a body mass index (BMI) greater than or equal to 30 kg/m^2. Economic indicators included personal income for the year 2012, three-year average unemployment rates for 2010 to 2012, and an annual average poverty measure for the years 2008 to 2012. Educational attainment was reported as an average of annual percentages of persons who had at least completed high school or obtained further education for years 2008 to 2012. Census population estimates were used for demographic information on the percentages of the population over age 65, non-Hispanic Whites, and those considered living in a rural setting. Estimates of health care costs reflected price-adjusted Medicare spending (Parts A and B) per enrollee in a given county. The percentage of those uninsured was determined in VA as those under age 65 that lack health care coverage. The measure for smoking was the percent of adults currently smoking and who reported smoking greater than or equal to 100 cigarettes. Deaths due to injuries were reported as an annual death rate from intentional (suicide firearm, homicide firearm, and suicide suffocation, etc.) and unintentional (motor vehicle traffic, poisoning, and falls, etc.) injuries per 100,000 population (RWJF 2014; ARC 2014).

Statistical significance was set, *a priori*, at $p < 0.05$. Two-tailed paired t-test analyses were performed on all coal and non-coal producing county data and assumed equal variances assumed unless otherwise noted. Pearson's correlation coefficients were determined for variables only in coal producing counties.

RESULTS

Coal counties were identified on the basis of annual production. In southwest VA total coal production per county was 2,709 ± 2,826 thousand short tons (mean ± standard deviation) for the year 2012 and included both underground and surface operations. The t-test statistic p-value = 0.04 and assumed unequal variance between coal producing and non-coal producing county groups (Table 1.)

All other group comparisons assumed equal variance. There was no significant difference between coal and non-coal counties in the percent obese of the adult population (age 20 and older) that had a BMI greater than or equal to 30 kg/m^2, 31.1 ± 2.2 and 29.9 ± 1.3, respectively ($p = 0.17$). Economic indicators of annual 2012 personal income ($31,523 ± 2,592 and $30,902 ± 3,307; $p = 0.73$), percent unemployment, averaged for three years, 2010 to 2012 (8.1 ± 0.9 and 8.9 ± 1.5; $p = 0.73$), and percentage of those below the poverty line, averaged from 2008 to 2012 (20.8 ± 3.9 and 17.4 ± 2.9; $p = 0.09$) were also similar in coal and non-coal producing counties. The measure of educational attainment, the mean percentage of the population completing high school from 2008 to 2012, was significantly lower in coal dependent counties (73.0 ± 4.69; $p = 0.05$) compared to in non-coal producing counties (78.3 ± 4.18; $p = 0.05$). The ethnic profile was similar in both county groups with approximately 93 to 94 percent of the population non-Hispanic white. The mean percent of the population over 65 years of age was significantly higher in the non-coal producing counties (19.8 ± 1.3; $p = 0.002$) compared to the coal producing counties (17.1 ± 1.7; $p = 0.002$). The percentage of the population living in a rural area did not differ between groups (70.7 ± 33.9 coal and 68.3 ± 36.7 non-coal; $p = 0.89$). The annual cost of health care in coal production counties did not differ from that in non-coal production counties ($11,014 ± 995 and $10,174 ± 1,139; $p = 0.13$). Likewise, the percent uninsured was also similar (18.6 ± 1.6 and 20.7 ± 2.6; $p = 0.07$). Percent smoking in both coal and non-coal producing counties in 2014 did not differ (27.0 ± 4.7 and 25.5 ± 4.3; $p = 0.56$); however, percent smoking was calculated with missing data because not

Table 1. Coal production and selected environmental factors associated with health in coal producing and non-coal producing counties in southwest Virginia (Values represent means ± standard deviations)

	Coal Counties[a]			Non-Coal Counties[b]			
Variable	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**P-value=**
Coal production, average thousand short tons, 2012	2,709	2,826	7	0	0	7	0.04*
Adult obesity, percent, 2014	31.1	2.2	8	29.9	1.3	9	0.17
Personal income, dollars, 2012	31,523	2,592	7	30,962	3,307	7	0.73
Unemployment 3 yr average, percent, 2010-2012	8.1	0.9	7	8.9	1.5	7	0.27
Poverty average, percent, 2008-2012	20.8	3.9	7	17.4	2.9	7	0.09
High school diploma average, percent, 2008 – 2012	73.0	4.7	7	78.3	4.2	7	0.05*
Non-Hispanic white, percent, 2014	94.4	3.5	8	92.9	5.9	9	0.55
Age, >65 years, percent, 2014	17.11	1.72	8	19.8	1.30	9	0.00***
Rural, percent, 2014	70.7	33.9	8	68.3	36.7	9	0.89
Annual health care cost/person, dollars, 2014	$11,014	$995	8	$10,174	$1,139	9	0.13
Uninsured, percent, 2014	18.6	1.6	8	20.7	2.6	9	0.07
Adult smoking, percent, 2014[e]	27.0	4.7	7	25.5	4.3	6	0.56
Injury death, per 100,000, 2014	109	22	8	83	16	9	0.01**

[a]Coal counties included Buchanan, Dickenson, Giles, Lee, Russell, Tazewell, Wise, including the city of Norton.
[b]Non-coal counties included Bland, Carroll and the city of Galax, Grayson, Scott, Smyth, Washington and the city of Bristol, Wythe
[c]p-values were for t-test, assumed equal variances except for coal production. *p < 0.05; **p < 0.01; ***p < 0.001
[d]N= number; number of counties for coal production, and ARC data for income, education, unemployment, poverty; *County Road Maps* data includes the number of counties and cities for health care, age, ethnicity, rural, uninsured, and injury.
[e] Smoking data, calculated with missing data.

all locations reported. There was a 24 percent higher rate of death due to personal injury in coal dependent communities compared to non-coal dependent counties (109 ± 22 vs. 83 ± 15; p = 0.01).

Pearson correlation coefficients on two-tailed t-tests on descriptive variables identified significant positive and negative trends for characteristics in coal and non-coal producing counties in southwest VA (Table 2).

There was a negative correlation with the percentage of obese patients and the death rate due to injury (r = -0.757; p = 0.03). The percentage of those completing a high school education was inversely correlated to smoking (r = -0.755; p = 0.05), coal production (r = -0.789; p = 0.040) and the percentage of the population below the federal poverty level (r = -0.782; p = 0.04). As the percentage of the population over 65 years of age increased the cost of health care declined, (r = -0.879; p = 0.004). Positively correlated to an increase in the percentage of the population living in rural areas was the percentage of the population unemployed (r = 0.757; p = 0.05).

Table 2. Pearson correlation coefficients between adult obesity and selected environmental factors in coal and non-coal producing counties in southwest Virginia

		Adult Obesity (percent)	
Variable		Correlation coefficient	P-value =
Injury Death Rate, per 100,000	Coal producing	-0.76	0.03*
	Non-coal producing	-0.16	0.7
High School Diploma, 2008-2012, percent	Coal producing	0.64	0.1
	Non-coal producing	-0.85	0.02*
Poverty, 2008-2012	Coal producing	-0.13	0.8
	Non-coal producing	0.85	0.02*
Age, persons 65 yrs and over, 2014	Coal producing	0.15	0.7
	Non-coal producing	0.81	0.008*
Unemployment, percent, 2012	Coal producing	-0.36	0.4
	Non-coal producing	0.96	0.001*

DISCUSSION

Coal producing counties did not differ from non-coal producing counties based on most current environmental factors. The exceptions were the lower percentages of high school graduates, the higher number of deaths per county due to injury, and a lower percentage of individuals aged 65 and older based on currently available data. Further study delineating a biochemical mechanism is needed if a true cause-effect relationship is to be confirmed between the environmental effects of coal production and health related factors. While genetics and biology are important contributors to chronic diseases, many environmental factors are widely recognized for their contributions to obesity. In general, over several decades adult obesity prevalence rates escalated regionally, nationally and globally (CDC 2015). Hendryx and coauthors have stated that environmental effects of MTR, i.e., coal dust, chemical exposure in the mines and second-hand, and chemicals used in the coal production, have been causative factors for various chronic health conditions in Appalachia, including obesity. However, from our current findings and prior literature review the data did not supported this view (Meacham et al. 2012, 2013; Woolley et al. 2015).

While coal production has been the focus of recent reports on community health it is well known that many other environmental factors have great bearing on community health. Our current study reports that southwestern VA counties with and without coal production were similar geographically and demographically and had similar economic and health characteristics. County level measures for both study groups were statistically similar for percentages of adult obesity, smoking, income, poverty, unemployment, health care costs, insurance coverage, rurality and ethnicity.

There were only a few demographic measures that significantly differed between the coal and non-coal producing counties. Educational attainment was higher (based on high school graduation completion reports for those aged 25-44 years) in non-coal producing counties than in coal producing counties. There was no observable explanation for this distinguishing association. Furthermore, academic opportunities beyond high school exist in the coal producing counties, such as the University of Virginia at Wise, the Appalachian School of Pharmacy, the Appalachian School of Law, and the

Southwest VA Community College. It is also possible that those with more education were able to relocate, leaving the coal-producing counties during the economic recession (2008-2012) which triggered mine closures and high numbers of employee layoffs. In just one year (2012) employment in VA mines was down 16 percent (EIA, 2014).

Previously reported were the differences in prevalence of obesity across various ethnicities, educational attainment levels and a general observation of higher obesity rates in women than men (CDC 2014). While this study did not report on gender it was also not possible to detect race/ethnicity differences due to the lack of diversity in southwest VA. Unlike findings from national studies, a correlation was not observed between the prevalence of obesity and educational attainment in southwest VA, likely due to the relatively slight difference in educational attainment and the lack of any difference in prevalence rates of obesity between the two study groups.

Although these specific factors lack formally assigned relative degrees of importance, the complex but modifiable social and cultural factors are key targets for future interventions. For example, previous reports noted breastfeeding and improvements in maternal and child obesity (CDC 2014; Moreno et al. 2011). Also, cultural differences for body images, previous threats of, or experiences with, under-nutrition and racial/ethnic or personal preferences in physical activity levels all possibly contribute to perceptions of healthy body weights The Appalachian culture is known to hold cultural values that have been maintained for generations which could include different perceptions of healthy body images. For many, their environment also consists of limited opportunities for physical activity, encourages excess screen time and promotes high-calorie, low-nutrient value foods and beverages. (McGarvey et al. 2011; O'Brien and Denham 2008; RWJF 2014; Williams et al. 2008).

Also not easily explained were the significantly higher percentage of persons aged 65 and over in non-coal production counties (19 percent) compared to the coal counties (17 percent). In Virginia the percent of those 65 years of age and older ranged from 6 to 33 percent with an overall 13 percent. Demographic descriptors for communities generally remain stable over time and provide cultural context for understanding health care data (RWJF 2014). There was a significantly higher rate of death due to personal injury in coal counties in southwest VA. Deaths due to injury serve as an indication of higher-risk personal behaviors. Injury deaths themselves are considered an indicator of personal and community safety awareness and may coincide with the slightly younger population and lower level of educational attainment in coal counties. Using 2006-2010 data, VA reported a range of injury deaths from 23 to 154 per 100,000 persons with a state average of 53. In the US deaths due to injury in 2010 were one of the leading causes of death, with unintentional injuries 5th and intentional injuries 10th (RWJF 2014). The leading causes of unintentional injury death were, in order, from motor vehicle traffic, poisoning, and falls. The leading causes of intentional injury death were, in order, from suicide firearm, homicide firearm, and suicide suffocation. Unintentional injuries were a substantial contributor to premature death and the leading cause of death in 2010 for between infancy and age 44. Injuries overall account for 17 percent of all emergency department visits and falls account for over one third of those visits (RWJF 2014). The overall burden of injuries was not captured by an injury mortality rate since these data do not include non-fatal injuries with large costs due to emergency room visits and time off work (RWJF 2014).

Behavior Risk Factor Surveillance System (BRFSS) data also indicate high rates of mental illness, frequently associated with higher-risk personal behaviors (BRFSS 2015; Zhang 2008). Mental health, often accompanied with substance abuse and overuse of prescription drugs, and physical health are inextricably linked. Evidence has shown that mental health disorders, i.e., depression, are strongly

associated with the risk, occurrence, management, progression, and outcome of serious chronic diseases and health conditions, including diabetes, hypertension, stroke, heart disease and cancer (Healthy People 2020, 2015).

Smoking is also an indicator of a population's cultural 'norms' and its general attentiveness to health behaviors and personal responsibility for health. Smoking was reported as the percent of adults reporting having smoked at least 100 cigarettes and currently smoking every day or most days. Smoking among adults was 25-27 percent in southwest VA counties, an estimate almost 50 percent higher than the state average of 18 percent (based on 2006 to 2012 annual data) (RWJF 2014). Current data indicate that each year approximately 443,000 premature deaths can be attributed to smoking in the US. Cigarette smoking is identified as a cause of various cancers, cardiovascular disease, and respiratory conditions, as well as low birth weight and other adverse health outcomes. Given that not all counties reported data, the measure of smoking prevalence has relevance as measuring the prevalence of tobacco use in the population can alert communities to potential adverse health outcomes and be valuable when assessing the need for cessation programs or the effectiveness of existing programs.

Nelson et al. (2001) reviewed the reliability and validity of the BRFSS smoking measure by analyzing studies that used BRFSS data and studies that used data from other sources. They found high reliability and high validity for the "current smoker" responses (RWJF 2014). This confirms that BRFSS survey data are a fairly accurate portrayal of the population's smoking behavior. Because the BRFSS only surveys adults (ages 18 and older), a weakness of the *County Health Rankings* measure is the lack of data on adolescent smoking. Also, new methods using biomarkers have shown that not all smokers are exposed to the same level of contaminants (Delnevo et al. 2009). The simple "current smoker" status question that survey data provides does not capture the thousands of chemical compounds in cigarettes and cigarette smoke nor take into account the effects of secondhand smoke.

Lack of access to quality health care is often attributed to poor health outcomes, i.e. obesity and its comorbidities. Lack of access may be a consequence of high health care costs. Health care costs reported in the current study were reflected as the annual price-adjusted Medicare spending (Parts A and B) per person and reflect the efficiency of an area's health care system. In VA this cost ranged from $4,390-$12,510, with an average of $8664, in 2011. In southwest VA the health care costs for coal and non-coal counties were approximately 34 percent of annual incomes. The state average for health care costs in 2015 were 18 percent, with $8,803 the average health care coast per person and personal incomes $48,838, thus almost half that relative to annual incomes in southwest VA. An additional indicator for access to care was the percentage of uninsured (19-21 percent) as compared with the state average (17 percent), top range 28 percent. Lack of insurance coverage was a notable barrier to accessing needed health care. (RWJF 2014).

LIMITATIONS

There are several limitations to this study. Health is the product of both genetic and environmental factors. Genetic factors were not considered in this study. The usefulness of BMI measures is often debated. Self-reported survey responses to health, i.e., body weight and height, are not as reliable as actual measures. Self-reported weight and height survey responses for BMI calculations generally underestimate obesity. However, BMIs are considered reliable and valid self-reported measures that also serve as 'proxy' measures for healthiness of food habits and exercise. Many reputable national descriptive epidemiological studies rely on self-reported survey responses and are comparable over time and place when consistently administered. Additionally, county level data are a commonly available

measure, and while ideally individual data would be preferred it is more difficult to obtain. This study did not collect data on children or report on gender known to be important in obesity prevention intervention design.

CONCLUSION

Cause and effect relationships have not confirmed and by design cannot substantiate an environmental impact of MTR on chronic health conditions. Our data support the need to reduce the prevalence rates of obesity to reduce the prevalence of chronic diseases. Risk factors for obesity include a multitude of environmental factors that are modifiable. Time, effort, expertise and resources should be invested to promote geographically specific intervention programs that promote education, income stability, access to care and positive health behaviors to continue to the reduction in prevalence rates of obesity documented for southwest VA. While future studies may link coal production to prevalence of chronic health conditions in southwest VA, our data support the need to address now the environmental concerns that will economically stabilize and effectively improve human health in all coal-mining communities.

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