Childhood Asthma in Rural-Urban Areas

Michael Hendryx, PhD; Matthew Gurka, PhD; Melissa Ahern, PhD; and Heidi Putman, PhD

West Virginia Rural Health Research Center
West Virginia University, Morgantown, WV

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EXECUTIVE SUMMARY

Background and Purpose: Asthma is one of the leading causes of chronic illness among children and the most commonly reported cause of childhood disability.[1] Rates of childhood asthma in the US have been increasing over the last several decades such that the rise in asthma prevalence has been labeled as an epidemic. The causes of this increase are not well known but may be related to factors such as increased impact of environmental allergens, indoor and outdoor air pollutants, increased obesity rates, and inadequate early immune system exposures.[2] Research specific to prevalence of asthma among rural children is limited and has resulted in conflicting findings which may reflect differences in exposures across different types of rural settings. The current study assesses rates of lifetime and current asthma for children across the rural-urban continuum for the U.S. The study examines how asthma may be related to rural areas adjacent or non-adjacent to larger population centers, to variation in measures of air quality, to varying levels of agricultural and animal production, and to other characteristics such as obesity, race/ethnicity, or health insurance.

Methods: The study design combines several national secondary data sources to test four hypotheses: 1) Rates of childhood asthma will not differ between urban and rural areas, reflective of the multiple causes of asthma among children. However, the study hypothesizes that: 2) Children in rural areas are at greater risk for asthma when they live in areas adjacent to metropolitan or micropolitan areas versus children in non-adjacent rural areas; 3) asthma rates will be higher for children in areas of high farm animal production compared to areas of lower animal production; and 4) asthma rates will be significantly and positively associated with poorer air quality in both rural and urban areas.

Data on childhood asthma were taken from two national surveys, the 2006 Behavioral Risk Factor Surveillance System (BRFSS) and the 2007 National Survey on Children's Health (NSCH). Data on farm animal and crop production were from the US Department of Agriculture (USDA). Air quality data on counties exceeding air quality standards for the years 1990-2007 were taken from the Environmental Protection Agency (EPA). Rural-urban designation and population demographics were taken from the 2008 Area Resource File.

County rural-urban designations were based on Urban Influence Codes ranging from 1 to 12. Analyses include metropolitan versus non-metropolitan codes, and analyses for metropolitan, micropolitan, and non-core codes. The study also examines differences for rural counties that are adjacent or non-adjacent to metropolitan or micropolitan counties.

Multilevel logistic regression models were used to investigate childhood asthma prevalence as functions of rural-urban status, air quality, agricultural production, parental smoking, race, health insurance, and other demographic variables.

Results: The sample size for the NSCH was 63,918 compared to 30,349 for the BRFSS, and the NSCH covered the entire nation (3,141 counties) whereas the BRFSS covered only 768 counties. Hypotheses 1 and 2 were supported, but hypotheses 3 and 4 were largely not supported:

Hypothesis 1: Rates of childhood asthma will not differ between urban and rural areas.

- Overall asthma rates were not different between rural and urban areas in either sample.

Hypothesis 2: Children in rural areas are at greater risk for asthma when they live in areas adjacent to metropolitan or micropolitan areas versus children in non-adjacent rural areas.

- Using the NSCH findings, which is larger and perhaps more representative of the nation than the BRFSS, asthma rates for rural children were significantly higher when those children were living adjacent to metropolitan or micropolitan areas, compared to nonadjacent rural children.

- Hypothesis 3: Asthma rates will be higher for children in areas of high farm animal production compared to areas of lower animal production. An association between animal production and asthma was found in only only analysis: for children aged 6-11 (Table 4), greater total animal production was related to higher asthma risk in the BRFSS sample. No significant effects were found for the NSCH sample.

Hypothesis 4: Asthma rates will be significantly and positively associated with poorer air quality in both rural and urban areas

- After controlling for other risk factors, there were no significant relationships between EPA air pollutants and childhood asthma, with one exception: counties that exceeded EPA standards for carbon monoxide had higher asthma rates for children aged 6-11 as measured by the NSCH.

Person-level risk variables were not a focus of the study. However, these variables had stronger associations with asthma risk than the county-level agricultural or air pollutant data. In particular, rural or urban children who were obese, in low income families, racial minorities, or lacked health insurance had significantly increased asthma risk.

Conclusions: Overall rates of asthma did not differ between rural and urban areas, except that rural children living in counties adjacent to more populous centers were at higher risk compared to children not adjacent to more populous centers. Agricultural variables, including crop and animal production that are largely based in rural areas, were usually not related to asthma risk when controlling for other risk variables. EPA air quality data available to the public are limited, with incomplete geographic coverage of rural areas, and suggest the need for policies to expand geographic coverage; incomplete coverage and limited outcome measures may have limited the ability to detect air quality and asthma associations. As has been observed in other studies, the highest policy priorities may include those to promote health insurance coverage, reduce obesity, and improve children's socioeconomic conditions to reduce asthma prevalence in both urban and rural areas. Policy recommendations include a need for increased attention to the primary prevention of childhood asthma.

INTRODUCTION

Asthma Risks

Asthma is one of the leading causes of chronic illness among children and the most commonly reported cause of childhood disability.[1] Asthma-related disability impairs individual activity ability, and has substantial social costs associated with increased burden on the educational and medical care systems.[1] Rates of childhood asthma in the US have been increasing over the last several decades such that the rise in asthma prevalence has been labeled as an epidemic.[2] The causes of this increase are not well known but may be related to factors such as increased impact of environmental allergens, increased obesity rates, inadequate early immune system exposures, and increased levels of air pollutants both indoors and outdoors.

To the extent that children have become more sedentary and spend more time indoors, potential exposures to poor indoor air quality may have increased in recent years. Potential indoor exposures associated with asthma include household mold or dust,[3] exposure to secondhand tobacco smoke,[4] and penetration of outdoor air containing traffic particulates.[5,6] Other studies of asthma related to both indoor and outdoor exposures have found associations with ozone, sulfur dioxide, nitrogen dioxide, and environmental allergens.[7]

Indoor and outdoor particulate exposures are often from the same sources. For example, particulates from outdoor internal combustion engines can impact indoor air quality and children's asthma symptoms.[6] Other studies of outdoor settings have found associations between childhood asthma and proximity to high-traffic roads.[5] An important source of particulate exposure with significant indoor and outdoor impacts is that of biomass burning including wood burning. Biomass burning is the largest source of air pollution in many rural areas.[8] It is used for heating, clearing forests, and disposing of crop stubble, trash, and wood. Biomass burning produces carbon dioxide, carbon monoxide, particulates and polycyclic aromatic hydrocarbons.[9] Indoor wood burning has been associated with significant increases in both indoor and outdoor particulate concentrations.[10] Studies show a significant association between asthma prevalence in children and exposure to woodsmoke.[11] Coal dust from surface coal mining has also been associated with increased asthma.[12]

Childhood asthma prevalence is highest among African Americans, followed by Hispanics and Whites. Among all racial and ethnic groups, childhood asthma prevalence increases with age.[13] Childhood asthma is more prevalent among males than females, nearly twice as prevalent among poor families and single parent families, and more prevalent in the Northeastern U.S. relative to other regions;[1] these patterns may reflect the risks associated with low socioeconomic status such as poor quality housing, and exposure to greater indoor and outdoor air pollutants, although reasons for the gender differences in childhood asthma are unknown.

Rural-Urban Differences

Research to address childhood asthma specifically in rural settings is limited and presents conflicting results. In some studies, rural children had lower asthma prevalence than urban counterparts.[14-16] All rural environments are not the same, however, as another study found that 5% of rural children in Canada who lived in farm environments had asthma, whereas rural children who did not live in farm environments had a higher asthma prevalence rate at 9%.[17] Urbanization may increase asthma rates and symptoms due to higher levels of air pollutants, but asthma may also be triggered by crop allergens, weeds and wildflowers, biomass smoke, dust, and animal dander, which are more prevalent in some rural settings. Research has found lower asthma rates among farm children compared to urban children, but higher rates among farm children exposed to certain activities such as hog production.[18-19] Some research suggests that families who live in rural environments develop a level of immunity to plant and animal allergens that are typically associated with asthma,[2,20] although other research suggests that urban exposures are key and that lower asthma rates in rural areas reflect lower urban-related risks rather than a rural protective effect.[21]

Much of the research on rural-urban differences in asthma prevalence has been based on locally specific comparisons and few studies have been done on a national geographic scale. There is also, in general, limited research on asthma among children in rural areas, with most prior research focusing on urban children.[22,23] The current study assesses rates of lifetime and current asthma for children in rural and urban areas of the U.S. The study examines how asthma may be related to measures of air quality in rural areas, to residence adjacent or non-adjacent to larger population centers, and to residence in areas of varying levels of agricultural and animal production. The study also examines how asthma may be related to other characteristics such as obesity, race/ethnicity, or health insurance.

Results of the study may help to inform rural health care policy by identifying the distribution of childhood asthma across rural settings and its relationships to risk variables. Policy responses regarding prevention and treatment of childhood asthma may be informed by the results. Additional policy implications may be suggested regarding air monitoring or air quality in rural areas.

METHODS

Hypotheses and Specific Aims

Study hypotheses are: 1) Rates of childhood asthma will not differ between urban and rural areas, reflective of the multiple causes of asthma among children. However, the study hypothesizes that: 2) Children in rural areas are at greater risk for asthma when they live in areas adjacent to metropolitan or micropolitan areas versus children in non-adjacent rural areas; 3) asthma rates will be higher for children in areas of high farm animal production compared to areas of lower animal production; and 4) asthma rates will be significantly and positively associated with poorer air quality in both rural and urban areas.

The hypotheses will be addressed by completing the following specific aims:

Specific Aim 1 – The first aim is to derive estimates of childhood asthma prevalence for rural and urban counties, including metropolitan, micropolitan, and non-core counties, as well as rural counties adjacent and non-adjacent to larger population centers.

Specific Aim 2 – The second aim is to identify potential environmental exposures that may contribute to childhood asthma prevalence across U.S. counties. Data collection efforts will focus on air quality, exposures to agricultural and livestock production, and proximity to urban locations.

Specific Aim 3 – The third aim is to link data on potential environmental exposure with childhood asthma prevalence data. Statistical methods such as hierarchical logistic regression will be used to assess association between childhood asthma prevalence and potential environmental exposures. Models will investigate childhood asthma prevalence as functions of rural-urban setting, air quality, agricultural and animal husbandry activity, race, health insurance, obesity, and other variables.

Design and Rural-Urban Designations

The study is a secondary analysis of existing data merged from multiple sources to investigate childhood asthma in relation to person and environmental risk variables. Some variables are measured at the person level and some at the county level; statistical models (described below) account for this multi-level design and for the complex sampling designs of the surveys.

Counties were differentiated based on rural-urban status for analyses. County rural-urban designations were based on the 2003 US Department of Agriculture Urban Influence

Codes ranging from 1 to 12. Table 1 lists the urban influence codes used for the study. Analyses were conducted for metropolitan (codes 1 and 2) versus non-metropolitan (codes 3-12) areas, as well as for metropolitan (1-2), micropolitan (3, 5, 8), and non-core (4, 6, 7, 9-12) areas. Unless otherwise specified, the term rural will be used to refer to non-metropolitan areas. Differences were also examined for non-core counties that are adjacent (codes 4, 6, 7, 9, 10) or non-adjacent (codes 11-12) to metropolitan or micropolitan counties.

Table 1: Urban Influence Codes

2003 Urban Influence Codes		
Code	**Description**	**Number of counties**
1	In large metro area of 1+ million residents	413
2	In small metro area of less than 1 million residents	676
3	Micropolitan area adjacent to large metro area	92
4	Noncore adjacent to large metro area	123
5	Micropolitan area adjacent to small metro area	301
6	Noncore adjacent to small metro area and contains a town of at least 2,500 residents	358
7	Noncore adjacent to small metro area and does not contain a town of at least 2,500 residents	185
8	Micropolitan area not adjacent to a metro area	282
9	Noncore adjacent to micro area and contains a town of at least 2,500 residents	201
10	Noncore adjacent to micro area and does not contain a town of at least 2,500 residents	198
11	Noncore not adjacent to metro or micro area and contains a town of at least 2,500 residents	138
12	Noncore not adjacent to metro or micro area and does not contain a town of at least 2,500 residents	174
Total U.S.		3,141

Data Sources

Asthma prevalence: Childhood asthma prevalence was derived from two data sources. First, data were obtained from the Centers for Disease Control and Prevention (CDC) 2006 Behavioral Risk Factor Surveillance System (BRFSS), which is a dataset where survey respondents are identified by the county they live in. A child less than 18 is selected randomly from the children living in the household. Lifetime childhood asthma prevalence was assessed for this child by the question: "Has a doctor, nurse, or other health professional ever said that the child has asthma?"[24] Responses were coded 'yes' or 'no.'

The second source of data on childhood asthma was the 2007 National Survey of Children's Health (NSCH) from the National Center on Health Statistics. Children whose parent answered "yes" to the question "Does your child currently have asthma?" were defined as having asthma for the purposes of this analysis.[25] Two investigators (Drs. Hendryx and Gurka) traveled to the National Center on Health Statistics offices in Hyattsville, Maryland to access these data. This was necessary because the variable identifying the child's county of residence is not available on the public use data files, but was available on-site after the investigators completed the required confidentiality training. All analyses had to be completed on-site and no data could be removed from the national office.

The analysis was stratified by age group given the parent-report nature of the asthma questions and the different phenotypes of childhood asthma.[26] Specifically, "transient early wheezing" is a common form of wheezing among children less than six years of age that is not defined formally as asthma.[26,27] To be conservative and examine only children with true asthma, children less than six years of age were excluded from the study. Secondly, many children develop asthma later in childhood ("late-onset wheezing"), rather than the more severe "persistent wheezing" that some children have throughout childhood. In an attempt to examine risk factors for each of these latter two types of asthma, the analysis was stratified by age group: children aged 6-11 and 12-17 years.

Results are reported separately for the BRFSS and NSCH asthma prevalence estimates. Separate analyses allow for testing the sensitivity of findings to one data source or another. Consistent results from both data sources would suggest more confidence in the findings.

Air quality data: Data from the Environmental Protection Agency (EPA) Green Book Attainment Areas were used to identify counties with documented air quality problems from 1990 through 2007.[28] These years were selected to represent exposure years corresponding to children aged 17 and under in 2007. Attainment data were recorded for levels of ozone, carbon monoxide, sulfur dioxide, and particulate matter (PM10). (The EPA also reports non-compliance for PM 2.5, nitrogen dioxide and lead, but the number of counties non-compliant with these standards was small and therefore not analyzed for this study.)

Counties were scored as non-compliant if they had one or more year in which they were non-compliant during the 1990s, and again for one or more non-compliant years in the 2000s. Asthma was analyzed separately for younger (aged 6-11) and older (aged 12-17) children; for older children non-compliance was investigated for both newer air quality violations (violations occurring in the years 2000-2007) and older violations (occurring in the 1990s), while for younger children only violations in the 2000s were counted because those children were not yet born in the 1990s.

Agricultural data: Amounts of agricultural production and size of livestock populations were found from the US Department of Agriculture (USDA).[29] Acres within the county committed to harvested crops as a percent of total county acres were calculated separately for corn, wheat, hay, and total production (which also included multiple other types of crops). Number of farm animals per total county acres was calculated separately for cows, pigs, chickens, sheep, and total numbers; at the time of the study these figures were available most recently for the year 2005.

Analyses

Analyses included descriptive summaries of study variables. Then, statistical tests were conducted to answer study hypotheses. Chi-square tests were used for bivariate categorical comparisons. Logistic multivariate regression was conducted to estimate and compare the odds of asthma for the populations of children from each database. These models include factors at the level of the child and family as well as variables on the county-level (i.e., EPA data on air quality, USDA data on agricultural and livestock production, and USDA data on proximity to urban/metropolitan locations.) SAS "surveyfreq" and "surveylogistic" procedures were used to account for the survey weighting and the complex multi-level sample design, which also accounts for the correlation among participants in the same sampling area. Covariates selected for the regression models were comparable but not identical between the BRFSS and NSCH datasets due to variability in the items available for analysis from each questionnaire. To obtain a parsimonious model, a backwards selection process was used, in which a full model was first fit, and then individual variables were removed in a stepwise fashion based on lack of significance. The final model includes covariates whose p-values are less than 0.15. Rural-urban designation, EPA air quality ratings, and agricultural data were not subject to backward selection; they were retained in final models regardless of p-value so their effects could be evaluated to answer study hypotheses.

Results

Results are presented for the BRFSS and the NSCH separately, and for children by age group (children aged 6-11, 12-17, and combined.) There are results reported for the main independent variables of interest (air quality and agricultural data) before and after controlling for other risk variables. These results are described in more detail below according to the four study hypotheses.

Hypothesis 1

Rates of childhood asthma will not differ between urban and rural areas, reflective of the multiple causes of asthma among children.

BRFSS: The BRFSS sample size for these tests was 30,349. Of these, 4,743 children (15.6%) overall were reported to have lifetime asthma. Based on BRFSS survey results, rates of childhood asthma were not significantly different between metropolitan (14.5%) and non-metropolitan (13.9%) areas. Rates were also not significantly different between metropolitan (14.5%), micropolitan (13.7%) and noncore (14.5%) areas. Results are summarized in Table 2. The results of this table show that Hypothesis 1 was supported, as there were no differences in asthma rates by these rural-urban designations.

***NSCH*:** The NSCH sample size was 63,918. Of these, 6,477 children (10.1%) overall were reported to have current asthma. Rates of reported lifetime asthma were thus higher in the BRFSS sample compared to the rates of current asthma reported in the NCHS sample, likely reflecting differences between lifetime and current asthma. The results of the NSCH analysis (top of Table 2) show that Hypothesis 1 was supported, as there was no significant difference in asthma rates by rural-urban designation when rural areas are defined as non-metropolitan, or when metropolitan-micropolitan-noncore areas were compared.

Table 2: Children's asthma rates by rural-urban designations based on the 2006 BRFSS and the 2007 NSCH.

	BRFSS (N=30,349)		**NSCH (N=63,918)**	
	N (%) with lifetime asthma	p<	N (%) with current asthma	p<
Metropolitan County				
Yes	3624 (14.5)	.44	4811 (10.2)	.60
No	1119 (13.9)		1666 (10.0)	
Metropolitan-Micropolitan-Noncore				
Metropolitan	3624 (14.5)	.60	4811 (10.2)	.77
Micropolitan	770 (13.7)		955 (10.1)	
Non-Core	349 (14.5)		711 (9.9)	
Urban Influence Code Categories				
Metropolitan	3624 (14.5)	.78	4811 (10.2)	.01
Micropolitan and adjacent to metro	306 (14.1)		534 (11.3)	
Non-core and adjacent to metro or micro	284 (14.3)		534 (9.9)	
Micropolitan and non-adjacent to metro	464 (13.2)		421 (8.9)	
Non-core and non-adjacent to metro or micro	65 (15.4)		177 (9.8)	
Adjacent or non-adjacent to metro or micro (non-metro only)				
Adjacent	590 (14.2)	.53	1068 (10.6)	.01
Non-adjacent	529 (13.4)		598 (9.2)	

Hypothesis 2:

Children in rural areas are at greater risk for asthma when they live in areas adjacent to metropolitan or micropolitan areas versus children in non-adjacent rural areas.

Hypothesis 2 was not supported by BRFSS data, as there were no significant differences in asthma rates for children living adjacent or non-adjacent to metropolitan or micropolitan areas. See the figures at the bottom of the BRFSS column, Table 2.

In contrast to the BRFSS, Hypothesis 2 was supported using NSCH data. There was a significantly ($p<.01$) lower asthma rate for children living in rural areas that were non-adjacent to metropolitan or micropolitan areas (9.2%) compared to rural adjacent areas (10.6%). The highest rates of asthma were in metropolitan areas (10.2%) and in micropolitan areas adjacent to metro areas (11.3%); other non-metropolitan areas had lower rates. See the bottom figures of the NSCH column, Table 2.

Hypothesis 3:

Asthma rates will be higher for children in areas of high farm animal production compared to areas of lower animal production.

Hypothesis 3 was largely not supported (Tables 3-5). There was a lack of significant findings in the regression models that controlled for other independent variables for children of all ages, and children 12-17. The only exception was for children 6-11 (Table 4), where greater total animal production was related to higher asthma risk (odds ratio=1.003, 95% confidence interval=1.001, 1.006) in the BRFSS sample. Because this finding was present only for the smaller BRFSS samples and not the more comprehensive NSCH sample, it is possible that it reflects chance variation in the BRFSS sample rather than a real effect.

Table 3: BRFSS and NSCH Regression Models of Odds of Asthma, All Ages.

	BRFSS			NSCH		
Variables*	**Odds Ratio**	**95% CI**	**p-value**	**Odds Ratio**	**95% CI**	**p-value**
Male	1.51	(1.33, 1.70)	<0.0001	1.20	(1.03, 1.40)	0.02
Ethnicity (vs. Non-Hispanic White)						
Non-Hispanic Black	1.17	(0.96, 1.43)	0.12	1.25	(1.02, 1.54)	0.03
Hispanic	0.70	(0.53, 0.92)	0.01	1.09	(0.77, 1.54)	0.64
Other	1.28	(1.05, 1.57)	0.02	1.33	(1.01, 1.75)	0.04
BMI Category (vs. Normal Weight)						
Overweight	1.28	(1.11, 1.47)	0.001	1.30	(0.97, 1.74)	0.08
Obese	1.42	(1.24, 1.63)	< 0.0001	1.68	(1.37, 2.06)	< 0.0001
No Health Insurance	0.75	(0.63, 0.90)	0.001	--	--	--
Insurance Status (vs. Adequate Insurance)						
Inadequate	--	--	--	1.11	(0.88, 1.41)	0.36
Uninsured	--	--	--	0.78	(0.61, 0.997)	0.05
Child Aged 12-17 (vs. 6-11) **	0.92	(0.83, 1.02)	0.13	--	--	--
Low Income	1.34	(1.14, 1.58)	0.0005	1.26	(1.02, 1.55)	0.03
Non-English Speaking	--	--	--	0.34	(0.21, 0.53)	< 0.0001
"Other" Family Structure	1.36	(1.20, 1.54)	0.0001	1.35	(1.13, 1.61)	0.001
Metro County	1.04	(0.92, 1.17)	0.57	0.94	(0.76, 1.16)	0.56
Harvested acres of crops as percent of total county acres	0.75	(0.56, 1.01)	0.06	1.02	(0.61, 1.72)	0.93
Animal density	1.002	(0.999, 1.004)	0.06	0.999	(0.997, 1.001)	0.42
Ozone	1.04	(0.91, 1.20)	0.54	1.05	(0.86, 1.27)	0.65
Sulfur Dioxide	0.97	(0.66, 1.43)	0.89	1.09	(0.70, 1.69)	0.71
Particulate Matter < 10 microns (PM-10)	0.99	(0.76, 1.28)	0.91	1.10	(0.79, 1.53)	0.58
Carbon Monoxide	1.06	(0.81, 1.38)	0.68	1.23	(0.90, 1.68)	0.19

*Variables excluded as a result of backward selection: household smoking & household education. Insurance status was measured differently on the BRFSS vs. the NSCH, and Non-English speaking family was available on the NSCH but not the BRFSS.

** Excluded as a result of backward selection from the NSCH but not the BRFSS.

Table 4: BRFSS and NSCH Regression Models of Odds of Asthma, Ages 6-11.

	BRFSS			NSCH		
Variables*	**Odds Ratio**	**95% CI**	**p-value**	**Odds Ratio**	**95% CI**	**p-value**
Male	1.59	(1.29, 1.95)	<0.0001	1.26	(0.96, 1.67)	0.10
Ethnicity (vs. Non-Hispanic White)						
Non-Hispanic Black	1.42	(1.09, 1.86)	0.01	1.49	(1.00, 2.22)	0.05
Hispanic	0.77	(0.50, 1.19)	0.23	0.99	(0.59, 1.66)	0.97
Other	1.32	(0.88, 1.96)	0.17	1.49	(0.80, 2.78)	0.21
BMI Category (vs. Normal Weight)						
Overweight	1.36	(1.10, 1.62)	0.003	1.43	(0.85, 2.40)	0.17
Obese	1.57	(1.26, 1.96)	<0.0001	1.35	(0.93, 1.98)	0.12
No Health Insurance	0.74	(0.57, 0.97)	0.03	--	--	--
Insurance Status (vs. Adequate Insurance)						
Inadequate	--	--	--	1.03	(0.70, 1.52)	0.87
Uninsured	--	--	--	0.80	(0.52, 1.23)	0.30
Low Income	1.33	(1.07, 1.67)	0.01	1.13	(0.79, 1.61)	0.52
Non-English Speaking	--	--	--	0.42	(0.15, 1.13)	0.09
"Other" Family Structure	1.52	(1.26, 1.83)	<0.0001	1.16	(0.81, 1.67)	0.42
Metro County	1.02	(0.84, 1.23)	0.84	0.85	(0.61, 1.18)	0.33
Harvested acres of crops as percent of total county acres	0.90	(0.56, 1.44)	0.65	0.61	(0.28, 1.31)	0.20
Animal density	1.003	(1.001, 1.006)	0.04	1.00	(0.997, 1.004)	0.88
Ozone	1.09	(0.88, 1.35)	0.42	1.06	(0.73, 1.55)	0.74
Sulfur Dioxide	0.87	(0.51, 1.50)	0.62	0.72	(0.33, 1.59)	0.42
Particulate Matter < 10 microns (PM-10)	0.93	(0.64, 1.35)	0.71	0.63	(0.40, 1.01)	0.05
Carbon Monoxide	1.08	(0.76, 1.53)	0.66	1.72	(1.09, 2.72)	0.02

*Variables excluded as a result of backward selection: household smoking & household education. Insurance status was measured differently on the BRFSS vs. the NSCH, and Non-English speaking family was available on the NSCH but not the BRFSS.

Table 5: BRFSS and NSCH Regression Models of Odds of Asthma, Ages 12-17.

	BRFSS			NSCH		
Variables*	**Odds Ratio**	**95% CI**	**p-value**	**Odds Ratio**	**95% CI**	**p-value**
Male	1.45	(1.22, 1.71)	<0.0001	1.18	(0.99, 1.41)	0.07
Ethnicity (vs. Non-Hispanic White)						
Non-Hispanic Black	0.98	(0.75, 1.27)	0.87	1.20	(0.96, 1.50)	0.11
Hispanic	0.63	(0.43, 0.92)	0.02	1.12	(0.75, 1.66)	0.57
Other	1.24	(0.93, 1.66)	0.14	1.30	(0.95, 1.78)	0.10
BMI Category (vs. Normal Weight)						
Overweight	1.22	(0.99, 1.50)	0.07	1.23	(0.93, 1.62)	0.14
Obese	1.30	(1.09, 1.56)	0.04	1.83	(1.41, 2.36)	< 0.0001
No Health Insurance	0.75	(0.60, 0.95)	0.02	--	--	--
Insurance Status (vs. Adequate Insurance)						
Inadequate	--	--	--	1.14	(0.90, 1.44)	0.28
Uninsured	--	--	--	0.79	(0.59, 1.05)	0.10
Low Income	1.36	(1.09, 1.70)	0.01	1.31	(1.03, 1.67)	0.03
Non-English Speaking	--	--	--	0.30	(0.17, 0.55)	< 0.0001
"Other" Family Structure	1.23	(1.04, 1.46)	0.02	1.41	(1.17, 1.72)	0.001
Metro County	1.04	(0.89, 1.22)	0.60	0.97	(0.74, 1.26)	0.79
Harvested acres of crops as percent of total county acres	0.64	(0.44, 0.94)	0.03	1.22	(0.66, 2.25)	0.53
Animal density	1.001	(0.999, 1.004)	0.32	0.999	(0.996, 1.001)	0.34
Ozone	1.01	(0.87, 1.18)	0.89	1.04	(0.84, 1.29)	0.71
Sulfur Dioxide	1.07	(0.74, 1.53)	0.73	1.15	(0.70, 1.89)	0.59
Particulate Matter < 10 microns (PM-10)	1.05	(0.78, 1.42)	0.73	1.29	(0.89, 1.88)	0.18
Carbon Monoxide	1.02	(0.75, 1.39)	0.89	1.11	(0.78, 1.56)	0.57

*Variables excluded as a result of backward selection: household smoking & household education. Insurance status was measured differently on the BRFSS vs. the NSCH, and Non-English speaking family was available on the NSCH but not the BRFSS.

Although not specific to a study hypothesis, greater total crop production was associated with lower asthma risk for 12-17 year olds in the BRFSS sample (Table 5).

Hypothesis 4:

Asthma rates will be significantly and positively associated with poorer air quality in both rural and urban areas.

Hypothesis 4 was not supported by BRFSS data. In the regression models shown previously (Tables 3-5), no significant relationship was observed between any of the assessed air pollutants (ozone, sulfur dioxide, PM-10, or carbon monoxide) and asthma.

However, Hypothesis 4 was partially supported by NSCH data. In the NSCH regression models adjusted for other variables (Tables 3-5), one significant relationship was observed between air pollutants and asthma. Carbon monoxide non-compliance was related to significantly higher asthma risk for children aged 6-11 when controlling for other variables (Table 4).

Childhood Asthma Prevalence by Other Demographic Variables

Our original hypotheses focused on potential environmental variables (animal production or air pollution) contributing to asthma risk. However, the results found little evidence for these associations and instead found stronger evidence that person-level demographic risks were present. Therefore, we report findings for these additional risk variables.

Individual-level risk variables for asthma were similar but not identical using the BRFSS and NSCH data sets. The regression model for all ages using BRFSS data (Table 3) showed that rates of childhood asthma were significantly higher for male versus female children, children of "other" race, when the parent was overweight or obese, and when there was low family income, "other" family structure (i.e., anything other than married), or no health insurance. Rates were lower for Hispanic respondents. These findings are consistent with prior research on socioeconomic risks related to asthma.

Using NSCH data for all ages (Table 3) resulted in similar findings. Asthma rates were higher for children who were male, African American or "other" race, obese, had no health insurance, were living in poverty, were non-English speaking, or had "other" family structure. Grouping children by age, there were more effects found for older children than for younger children. Older children in the NSCH sample were at greater risk for asthma when they were obese, living in poverty, non-English speaking, or of "other" family structure (that is, any structure other than married, including single, divorced or widowed.)

Note finally that rural-urban county designation was not related to asthma in any regression models in Tables 3-5.

Discussion

Rates of lifetime asthma overall were higher in the BRFSS sample, compared to rates of current asthma that were relatively lower in the NCHS sample. This would be expected in comparison of lifetime versus current rates. Rural-urban differences in the rates of asthma were not found in most analyses; the only exception was that the NSCH sample results indicated that childhood asthma rates in rural areas were higher when those areas were adjacent to larger population centers in metropolitan or micropolitan areas.

Of the two surveys, the NSCH had a larger sample and covered more counties than the BRFSS. The sample for the NSCH was 63,918 and included all 3,141 US counties; the BRFSS sample was 30,349 across 768 counties. Where discrepancies exist, it may be that the NSCH results should carry more weight because it is probably more representative of the nation as a whole.

Overall, there were few agricultural or air pollutant relationships observed in either sample. Air pollution is an established risk factor for asthma; the findings in this study likely reflect the limited sensitivity of the measure of exposure to detect effects. Other studies have established air pollutant risks on small geographic scales and more closely matched time periods between pollution and exposure.

Study Limitations. The current study was limited to county level assessments of air pollution measured, with a summary measure aggregated over multiple years. In addition, the EPA measures were limited to a yes/no recording of whether an established standard was exceeded, rather than a more exact measure of what the pollutant levels actually were. Any of these limitations, aggregation at the county level, aggregation over multiple years and summary yes/no measures, may be responsible for the inability to detect associations between air pollutants and asthma rates. There was a similar problem with the agricultural data in that county measures of number of animals or crop production may be too insensitive to individual-level children's exposures to detect effects. The BRFSS and NSCH surveys were done one year, in 2006 and 2007, respectively, which also creates imperfections between the time of the survey and the time of the environmental exposure assessments, making detection of effects more difficult.

Despite these limits, there were some findings for air pollutants and asthma in rural settings in the NSCH sample. Non-compliance with EPA standards for particulate matter and sulfur dioxide were related to higher asthma rates for 12-17 year olds in the bivariate analysis, but these relationships were not found in the regression models that controlled for other risks. There was an unexpected inverse relationship between carbon monoxide noncompliance and lower asthma in rural areas, probably reflecting a confound with other unmeasured asthma risks. In the multivariate context, NSCH data showed higher asthma risk for 12-17 olds in association with higher levels of carbon monoxide.

One analysis found higher asthma risk for younger children aged 6-11 as agricultural animal production increased. This was observed in the BRFSS sample but not replicated in the NSCH sample. Crop production was related to lower asthma risk among older children in the BRFSS sample; this may reflect healthier environments in agricultural areas, healthier agricultural populations, or the benefits of early exposure to allergens or other asthma risks. However, since this finding was not replicated in the NSCH sample, the finding may also reflect chance variation based on areas that happened to be represented in the BRFSS sample.

Perhaps most importantly, the study revealed that more traditional person-level risk variables were stronger correlates of asthma than risks related to agricultural production or air pollutants. This is consistent with results found by Guner[30] who reported that familial history of asthma was the strongest predictor of asthma in children, rather than rural or urban residence. Obesity, low income, and lack of health insurance were all associated with increased current or lifetime asthma risk in the current study. Other research has also identified low income or poverty as a risk factor for children's asthma;[22,31] low income children could be at greater risk for exposure to other asthma hazards such as indoor mold , indoor dust, tobacco smoke, or residence near air pollution sources such as highways or industry.

Policy Implications

Despite the limited significant statistical effects found in this study, the results suggest a number of important policy implications. First, the publicly available air quality environmental indicators may be too crude to detect effects. Better data on air quality in rural and urban areas that provide actual levels of PM, CO, SO2, etc. rather than dichotomous measures indicating only whether a standard in a given year was exceeded, may prove more useful for research purposes. In addition, EPA air monitors are not available in all counties and where they are absent, air quality is assumed in the EPA public database to be of good quality (i.e., to not exceed the standard). Air quality monitors are disproportionately absent in rural versus urban areas[31] and suggest the need to improve geographic coverage of air quality monitoring in rural areas. It would be hypothetically possible as policy responses to add additional monitoring stations to unrepresented areas, and to distinguish in public websites or reports the distinction between areas where air quality is known to be good and areas where data on air quality are unavailable.

Second, health care access is important. Children without health insurance are at greater risk for lifetime or current asthma than children with insurance. Efforts such as the Affordable Care Act that strive to provide better universal health care coverage for children are important in many ways, and could be expected to improve asthma treatment among its benefits.

Third, increased primary prevention efforts to reduce individual risks related to obesity and poor socioeconomic status are warranted. Relatively more attention has been placed on secondary prevention of asthma symptoms or exacerbations, which is important, but overlooks the contributions that primary prevention efforts can make. The National Heart, Lung and Blood Institute's (NHLBI) National Asthma Education and Prevention Program focuses on diagnosis treatment, and secondary prevention rather than primary prevention.[33] However, a report produced by the NHLBI on coordination of federal asthma activities recognizes the need for research on asthma causes and primary prevention.[34] Similarly, the description of the Healthy People 2020 Respiratory Diseases section includes a statement that there is a need to better understand the genetic and environmental causes of asthma, but in contrast, examination of the actual Healthy People 2020 Objectives includes none that address primary prevention.[35] The increasing prevalence of childhood asthma that has been labeled as an epidemic[2] might be reduced, thus reducing demands on the health care treatment system, by better understanding and reducing the initial causes of asthma.

SUMMARY AND CONCLUSIONS

Major study findings and policy implications include:

- Overall childhood asthma rates were not different between rural and urban children.
- However, rural children living adjacent to metropolitan areas were at greater risk for asthma than rural children in non-adjacent areas. This might be due to exposure of adjacent-residing children to more urban-related asthma risks, or due to less exposure of adjacent-residing children to protective factors such as agricultural production.
- Air pollution measures were largely not able to account for asthma risk in this study, but limitations to the sensitivity of those air pollution measures may account for the lack of observed effects.
- Contrary to expectations, there was little evidence that animal production levels increased risk for childhood asthma. This may reflect a true lack of relationship, or it may reflect limitations in the ability to measure individual children's exposure to farm animals.
- Person-level risks including obesity, poverty, racial minority status, and lack of health insurance were related to higher childhood asthma risk.
- There is a suggested need for improved environmental monitoring of air quality in rural settings.
- Attention should be placed on primary prevention efforts to reduce asthma risks associated with such factors as obesity or poor socioeconomic conditions.

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