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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. In some studies, rural children had lower asthma prevalence than urban counterparts.[3-5] 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%.[6] 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.[7-8] 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,[2,9] 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.[10]

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 urban areas 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 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. P values of <.05 are used to test statistical significance.

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

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. The results are described 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 1. 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 1) 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 1: 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 1.

In contrast to the BRFSS, Hypothesis 2 was supported using NCHS 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 1.

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. Table 2 shows the results for all ages. When analyses were conducted separately for younger (age 6-11) and older children (age 12-17) there was one significant finding: for children 6-11, 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 statistical chance or a Type I error rather than a real effect.

Table 2: 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.

Hypothesis 4:

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

Hypothesis 4 was also largely not supported. 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 (meaning the level of the pollutant was higher than the permissible amount) had higher asthma rates for children aged 6-11 as measured by the NSCH.

Person-level risk variables (such as insurance status, race, obesity or income) were not a focus of the study. However, as shown in Table 2, 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.

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 particulate matter, carbon monoxide, sulfur dioxide, 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[11] 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.[12] However, a report produced by the NHLBI on coordination of federal asthma activities recognizes the need for research on asthma causes and primary prevention.[13] 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.[14] 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 those associated with agricultural production.

- Air pollution measures were largely not able to account for asthma risk in this study, but limitations to the sensitivity of the 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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