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Rural health disparities in asthma care and outcomes

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Abstract

Fifty-nine million Americans (21% of the US population) live in rural areas of the United States. Compared to persons living in urban areas of the US, rural populations have lower income, a higher rate of government versus private insurance, and decreased access to health care. While there are reports of lower asthma prevalence in rural areas, the majority of this data has been published on international populations, with little available data looking at American urban versus rural asthma prevalence on a national scale or comparing rural to nearby urban cohorts in the US. A large body of literature, mainly generated from studies of rural Europe, suggests that lower prevalence may be due to beneficial effects of exposure to farm environments, but the extent to which this applies to the rural US, where a smaller proportion of the population engages in farming, is unclear. The United States has the additional covariate of having a higher proportion of African-Americans, who have a greater asthma burden than whites independent of socioeconomic status, clustered in cities. There is data indicating that rural patients have increased difficulty obtaining healthcare in general, and limited data suggesting that they receive inferior care for asthma. Future work is needed to more clearly define asthma prevalence and morbidity among residents of the rural US, as well as to identify interventions effective in this population.

Keywords

asthma; rural health disparities; hygiene hypothesis

What is rural?

The definition of rural varies somewhat even among different agencies of the United States government, but in general refers to those areas not included in a central city and its surroundings. The Bureau of Census in 2000 defined urban as those census blocks with a population density of at least 1,000 people per square mile, plus the adjacent blocks with a

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density of at least 500 people per square mile; furthermore, an urbanized area had to include at least 2500 people.^{1,2} In the 2000 Census, 59.1 million people, or 21% of the population, lived outside such areas and were classified as rural.²

Economic and Health Disparities in the Rural United States

Apparent from the above definition is that rural areas are heterogeneous in terms of their proximity to urban resources, with those areas on the fringe of a city generally enjoying better economic circumstances than those that are more isolated. Overall, however, rural areas suffer from greater poverty than urban areas: 47% of rural residents have family incomes of less than 200% of the federal poverty limit versus 27% of non-rural residents, and the median family incomes in 2001 were approximately \$32,000 for rural residents versus \$44,000 for non-rural residents.^{3,4} Rural residents are less educated than urban residents: in the 2000 Census, 23% had not completed high school versus 19% of urban residents, and only 16% had completed college versus 27% of urban residents.⁵ There are fewer minority individuals in rural areas (17% in rural areas versus 49% in urban central cities versus 23% in urban areas outside of central cities), but those minorities are greatly disadvantaged: African Americans in rural areas have household incomes 40% less than rural whites, and 60% less than suburban whites.³

Overall, 17% of the non-elderly rural population lacks insurance, but when rural counties adjacent to cities are excluded, the figure increases to 24%. Of those who are insured, a higher proportion is insured under public programs like Medicaid, the State Children's Health Insurance Program (SCHIP), and Medicare due to increased poverty.^{3,4} Consequently, hospitals operate on thinner margins, with approximately half of rural discharges paid by Medicare, versus a third of suburban discharges. In addition, there are fewer physicians available: while 21% of the overall population is rural, only 9% of physicians practice in rural areas, with particular disparity in subspecialty care availability.³ Rural residents are 10-20% less likely than non-rural residents to receive preventive services like well visit exams, mammograms, and blood pressure, lipid, and colorectal cancer screening.^{4,6}

Prevalence of asthma in rural versus urban populations

Given the disadvantages rural Americans face in the broader healthcare system, the first question regarding the impact of asthma in rural communities is what is the relative prevalence of asthma in rural versus urban and suburban areas. There is surprisingly little data addressing this question, most of it international. In the International Study of Asthma and Allergies in Childhood Phase III (ISAAC III), 13.8% of 13-14 year olds and 10.8% of 6-7 year olds worldwide carried a diagnosis of asthma. The prevalence is somewhat higher in North America, Western Europe, and Australia compared to Africa, Latin America, and Asia, although this difference has narrowed since ISAAC I. While this data, when viewed by country and region, suggests that asthma is more prevalent in more populous and industrialized areas, the ISAAC studies generally had one to a few centers per country, always located in cities, and thus it is difficult to estimate worldwide asthma prevalence in urban versus rural areas from this data.⁷

Several international studies are available, however, that compare the prevalence of asthma in urban and adjacent rural areas, with all finding lower asthma prevalence in rural areas. Solé *et al.* analyzed ISAAC III data of 13-14 year olds from two Brazilian centers, Caruaru and Santa Maria, and found a significantly higher rate of wheezing ever, wheezing in the past 12 months, or lifetime asthma diagnosis in the children living in urban areas compared to those from rural areas.⁸ Yemaneberhan *et al.* conducted a household survey in Ethiopia of 9844 people from the urban, pre-industrial city of Jimma and 3032 people from three nearby rural communities. While the observed prevalence rates were low overall, rates differed significantly for rural and urban groups for self-reported asthma (3.6% urban, 1.3% rural) and wheeze in the prior year (3.7% urban, 1.2% rural).⁹ Keeley *et al.* examined reversible airways obstruction

(which they defined as a 15% decrease in peak expiratory flow with exercise correctable with salbutamol) in urban versus rural children in Zimbabwe. The rate of reversible airways obstruction by this definition was 5.8% and 3.1% in the two urban populations, statistically significantly higher than the 0.1% rate observed in the rural population.¹⁰ Korzyrskyj and Becker conducted a mail survey in Manitoba, Canada in 2002-2003 of households with 7 year old children, and found that families reported asthma in 14% of urban children compared to 8% of children from northern and 10% of children from southern rural Manitoba. It should be noted that this survey was limited by a poor response rate.¹¹

There is a paucity of studies comparing asthma prevalence in rural communities in the US to similar populations in nearby cities. In a study of Iowa schoolchildren, Chrischilles *et al.* conducted a mail survey using ISAAC questions of parents of 3090 children ages 6-14 in two rural Iowa counties. They found an overall prevalence of wheeze in the past 12 months of 19.1%, and a prevalence of doctor-diagnosed asthma of 12.4%. In multivariate analysis controlling for age, sex, and county, children who lived on farms versus those who lived in town in the same counties were less likely to ever wheeze (odds ratio [OR] 0.71, 95% confidence interval [CI] 0.58-0.87) or to experience wheeze in the last 12 months (OR 0.77, 95% CI 0.6-0.98).¹²

Perry *et al.* examined asthma prevalence in two school districts in the Delta region of Arkansas, an impoverished, rural and medically-underserved region of the United States. The majority of students were African American (97%) and had government-issued medical insurance (73%). Of the students completing the survey, which had an 81% response rate, 268/964 (28%) were considered at risk for asthma by previous physician diagnosis or a validated asthma algorithm diagnosis. The at-risk population was highly symptomatic and the majority (79%) had evidence of persistent asthma with 82% reporting activity limitations, 59% reporting frequent nocturnal symptoms, and 49% either hospitalized or treated in the emergency room for asthma in the preceding 2 years. These findings not only suggest asthma prevalence higher than national rates, but also reveal significant evidence of uncontrolled asthma in this rural, impoverished, predominately African American population.¹³

Most of the large American asthma prevalence studies (American Lung Association Trends in Asthma Morbidity and Mortality 2007, National Asthma Survey 2003, National Survey of Children's Health, Hospital Discharge Data System, National Hospital Discharge Survey, National Health Interview Survey) whose datasets could be analyzed to address national urban versus rural asthma prevalence in the United States unfortunately have not been utilized to assess rural asthma burden.^{14,15} In a report by Jackson *et al.* at the Rural Health Research Center at the University of Washington that analyzed Behavioral Risk Factor Surveillance System data for 2003, these investigators found a lifetime prevalence of asthma in urban American counties of 12% versus 11% for rural counties (n=264,648 and p<0.001).¹⁶

From the available data reviewed above, asthma appears to be less prevalent in rural than in urban international areas, and less convincingly so, in the rural US compared to urban areas of the US. Rural US populations with a large proportion of minority or low income residents seem to the contrary to have an exceptionally high prevalence of asthma. Furthermore, residents of the United States have a higher burden of asthma than residents of most areas of the developing world regardless of urban or rural residence.

Why might asthma be less prevalent in rural areas of the US?

There are several potential explanations for an overall decreased prevalence of asthma in rural areas, including the higher beneficial exposure of rural populations to farming in general and endotoxin in particular, and in the US, covariation of race with rural versus urban residence (references 17-54, discussed below).

The European farming hypothesis

Since Strachan's original paper inversely relating household size to allergic rhinitis and eczema¹⁷, a large body of evidence confirmatory of his "hygiene hypothesis" has emerged in studies of rural, mainly European farming communities. A number of these studies strongly support the idea that exposure to farming is one of the protective factors at work in rural populations. Riedler *et al.* surveyed parents of 2282 children age 8-10 in rural Austria, and skin tested 1137 of the children. In those rural children who lived on farms compared to rural children who did not live on farms, they found a lower prevalence of hay fever (3.1 vs 10.3%, $P = 0.0002$), asthma (1.1 vs 3.9%, $P = 0.017$), and positive skin test to one or more allergens, and odds ratios in a multivariate model accounting for parental education, living conditions, and diet remained significant until regular farm animal contact was added to the model.¹⁸ von Ehrenstein *et al.* carried out a cross sectional survey of parents of 10,163 children ages 5-7 in two rural Bavarian districts using ISAAC questions. Comparing farmers' children to children of non-farming rural parents, they found that the rate of hay fever and asthma decreased with additional farming exposure (no farming versus part time versus full time) and that the prevalence of any atopic disease similarly decreased in a dose dependent fashion with increased farm animal contact.¹⁹ Ernst and Cormier surveyed children 12-19 years old in school districts surrounding Quebec City, Canada, comparing 802 children from farming families with 397 non-farming rural children, and in multivariate analysis found lower risk of current wheeze (OR 0.70, 95% CI 0.52-0.95), asthma (OR 0.59, 95% CI 0.37-0.95), and positive skin test reactivity (OR 0.58, 95% CI 0.46-0.75) in the children from farming families.²⁰

A few characteristics of the farm populations in these and other similar studies¹⁸⁻²² merit further comment. First, since asthma prevalence and morbidity increase with lower socioeconomic status,²³⁻²⁶ it is important that the farmers in the above mentioned studies not represent a group with unexpectedly high socioeconomic status. While median incomes were not given in these studies, the farm families always had lower levels of educational achievement compared to non-farming controls, and educational level was controlled for in multivariate models. Additionally, European farmers do not appear to differ in wealth from their American counterparts; farming families on average earn approximately the median family income both in the US as well as in much of Western Europe.²⁷⁻²⁸

Secondly, in the two studies that reported prevalence of family history of atopy, it was significantly lower in farm children than in non-farm children.^{19,21} This argues that in farming populations, there may exist a "healthy worker effect," wherein atopic families would gravitate away from farming, pre-selecting for a less atopic farming population. Additionally, it may be that there is lower atopy among farming families because they have had a protective effect of farming for generations. However, this is a poorly studied issue²⁹ that clearly is not the only effect at work in farming families, as nearly all of these studies accounted for family history of atopic disease in their multivariate models and still found reduced atopic disease burden in farmers' children compared to non-farming rural controls.^{18, 19, 21, 22} More broadly, there is no data to suggest whether a healthy worker effect might exert a net influence on urban versus rural asthma prevalence.

A large body of work has identified exposure to endotoxin as an explanatory factor as to why children from the same rural communities have a lower prevalence of atopic disease when the family is engaged in farming. Braun-Fahrlander *et al.* surveyed parents of children ages 6-13 years old in rural areas of Germany, Austria, and Switzerland, and obtained blood samples and endotoxin measurements from dust from the children's bedding. Level of endotoxin exposure was inversely correlated with hay fever, asthma, and rate of positive blood IgE testing for specific allergens. When they exposed leukocytes from study children to lipopolysaccharide or Staphylococcal Enterotoxin B, production of TNF-alpha, IL-12, IFN-alpha, and IFN-gamma

were all inversely related to the child's endotoxin load, indicating immune downregulation induced by environmental exposure to endotoxin.³⁰

The relevance of endotoxin exposure to the prevalence of asthma in the rural US is uncertain.²³ Compared to the European Union, American farming is much more industrialized, involving many fewer people working much larger plots of land. In the US, about 3 million among 305 million Americans work part- or full-time on farms (of whom 1 million are hired laborers, who represent a poor, heavily minority, and often non-English speaking group of workers), versus 17.9 million among 490 million European Union residents (16.1 million of whom are the landholder or family of the landholder, and thus more likely to live on the land they work).³¹⁻³³ In addition, the average American farm is 431 acres (174 hectares) whereas the average European Union farm is 51 acres (20.7 hectares).^{31,33} Thus, a relatively smaller portion of the rural US enjoys the intimate contact with the land that has been shown to be associated with a reduction in atopic disease in rural European populations.

Furthermore, applying European hygiene hypothesis data to explain a somewhat lower prevalence of asthma in rural versus urban areas of the US assumes that rural American populations have higher endotoxin exposure than urban American populations. The environment in which many urban Americans live is arguably not any more sanitary than that of surrounding rural areas, and urban American children are exposed to situations that might be expected to increase endotoxin exposure, such as daycare, crowded schools, and multifamily housing.^{23,34,35} Two groups of investigators have measured endotoxin levels in urban American environments (New York City and Boston; references³⁶⁻³⁸), and interestingly, both groups observed a direct and not inverse correlation between endotoxin load and wheeze (although the correlation was inverse as expected for eczema rate versus endotoxin exposure). While one of these studies³⁶ points out that the urban endotoxin levels they measured are several fold lower than the levels measured in farm homes in European studies, they note that it is problematic directly comparing determinations made by different groups using different collection procedures and assays. As yet there is no data comparing endotoxin levels inside average (i.e. mostly non-farm) rural American households to levels inside nearby suburban and urban dwellings.

Race as a covariate in rural-urban asthma prevalence in the United States

The covariation of race with urban or rural residence in the United States may account for lower asthma prevalence in rural areas, as rural areas have a higher proportion of whites than urban areas, and African-Americans have a higher burden of asthma.^{3,23} Nelson *et al.* conducted a telephone survey in 1992-1993 of an integrated middle class community in Michigan, and found a lifetime prevalence of asthma of 12% in school-age African-American children and 6% in white children despite similar income and educational levels and low poverty rates in both groups.³⁹ Miller examined data from the 1988 National Maternal and Infant Health Survey and its 1991 longitudinal follow-up and found that as family income increased, asthma prevalence fell among white but not African-American children.⁴⁰ These studies suggest that demographic, and not strictly regional factors, may play a significant role in differences in asthma prevalence in urban and rural areas of the United States.

Other potential explanations for lower asthma prevalence in the rural US

Additional risk factors for the onset of asthma from childhood through young adulthood have been well characterized, including elevated serum IgE, perennial allergen sensitization (including dust mite, cockroach, dog, and cat), presence of atopy, exposure to tobacco smoke and other air pollutants, and winter viral infections/bronchiolitis.^(41-47; reviewed in 48 and 49) Consistent with a lower prevalence of asthma in rural areas, there is limited data indicating that the rate of cockroach sensitization is higher in urban areas.⁵⁰ Data for the rate of dust mite

sensitization in urban versus rural areas is mixed.⁵⁰⁻⁵² In contrast, bronchiolitis, which is a risk factor for the development of asthma, as well as smoking, are both more and not less prevalent in the rural US than in the urban US.^{47,53} Regarding other air pollutants that exacerbate respiratory disease, including nitrogen dioxide, particulates, and other organic compounds, some sources (vehicular traffic, industry) are more prevalent in urban areas, whereas others (combustion of organic fuels in the home) are more prevalent in rural areas, and the net impact of this issue on rural versus urban asthma is unclear.⁵⁴

The factors reviewed above offer explanations for a somewhat lower prevalence of asthma in the rural US compared to the urban US. The higher prevalence of African-Americans in US cities and the higher burden of asthma in this community independent of socioeconomic status seems to be a salient explanation for some of the differences in urban and rural asthma prevalence in the US. While a large group of studies has shown endotoxin to be a factor explaining decreased atopic disease in rural populations, particularly in Europe, rural US populations have much less exposure to farming than their European counterparts, and it is unclear to what extent this factor is relevant in the US.

Disparities in health care for rural asthmatic patients

As discussed earlier in the review, rural Americans have decreased ability to access care for asthma due to both economic disparities (lower income and higher rates of uninsured, under-insured, and government-insured residents) and supply disparities (lower rates of preventive screening suggesting difficulty accessing primary care, and lower relative supply of both primary care and specialist physicians in rural areas).^{3,4,6} Furthermore, rural residents who might otherwise be eligible for care must have the means to travel to the location of care. There is evidence that, compared to urban residents, rural Americans travel greater distances to obtain care⁵⁵, and greater distance to care is a risk for poor health outcomes and increased morbidity and mortality,⁵⁶⁻⁵⁸ including for asthma.⁵⁹

There is limited direct data, both international and from the US, indicating that those with asthma who live in rural areas receive inferior care for their asthma. Tong and Drake used hospital discharge and mortality data to show a higher rate of asthma related hospitalization and a higher case fatality rate for rural versus urban residents of New South Wales, Australia in the 1980s and early 1990s, but this study did not attempt to control for confounding variables.⁶⁰ Lum *et al.* reviewed charts of 3072 patients from 42 Canadian primary care practices and divided patients by urban or rural residence. The rural patients were more likely to be male, non-smokers, and younger, but they made more emergency department visits (38% of charts versus 17%, $p < 0.001$) and received more specialist referrals, suggesting increased difficulty accessing primary care.⁶¹ Consistent with this is a retrospective claims review study by Smith *et al.* of 1474 urban children with Medicaid insurance in Hartford, Connecticut showing that children with more asthma-related primary care visits in the preceding 12 months had fewer asthma-related emergency department visits (particularly if they had also filled an inhaled corticosteroid prescription), whereas those with more asthma-related emergency department visits had a lower rate of primary care visits for any reason.⁶² Withy and Davis analyzed emergency department insurance claims data for 7064 Hawaiians by urban or rural residence, and found that while urban and rural children had no difference in time to outpatient follow-up after an ED visit (suggesting equal access), rural adults were less likely than urban adults to have either a follow up office or emergency room visit for asthma in the month following an ER visit.⁶³

Finally, for this review, we analyzed county level data for yearly asthma hospitalization rate from a Tennessee Department of Health report on asthma in Tennessee⁶⁴ based upon whether each county was an urban central county, a non-central county within a Standard Metropolitan

Statistical Area (SMSA), or a rural county, as defined by the most recent Office of Management and Budget listing.⁶⁵ In the state report, data for all asthma related discharges in Tennessee from 2004-2006 was obtained from the Hospital Discharge Data System database, and was presented by the patient's county of residence and not the location of the hospital. When re-organized by urban or rural residence, this data shows that in Tennessee, the total number of asthma related hospitalizations per 100,000 people per year is 133 in urban central counties, 120 in non-central counties within the SMSAs, and 160 in rural counties. We combined this county data with US Census data for county populations and poverty rates⁶⁶ (Figure 1), demonstrating that rural counties in Tennessee have a higher burden of poverty, and that there is an association between poverty and asthma morbidity as measured by asthma hospitalizations. Whether this data indicates inferior ability to access timely and appropriate outpatient asthma care or a higher prevalence of covariates associated with worsened asthma is not known. Given the lower socioeconomic status of rural US populations compared to urban and suburban populations³⁻⁵ and previous work showing worsened asthma morbidity with lower socioeconomic status,²³⁻²⁶ differential urban-rural asthma morbidity is likely partly socioeconomic, independent of region of residence. In summary, while rural US populations have many socioeconomic disadvantages and are geographically isolated from healthcare, there is as yet only limited data generally showing worsened asthma outcomes compared to urban residents, and further study in this area is needed.

Conclusions

59.1 million people live in rural areas of the United States. While their experiences are heterogeneous, overall rural US populations face increased poverty and inferior health care for reasons related to insurance status and to poor access due to increased travel distance and lack of providers, particularly specialists. There is international data showing lower rates of asthma in rural areas, with limited confirmatory data regarding the rate of asthma in rural compared to urban areas of the US. The available data suggests that asthma prevalence in the rural US is greater than that seen worldwide, and not as significantly different from urban areas as in other countries. The hypothesis of lower asthma prevalence in rural areas is consistent with a large body of work mainly conducted in Europe identifying farming in general, and endotoxin exposure in particular, as protective against the development of asthma, but the extent to which this paradigm applies to rural US populations is unclear. An additional factor in the United States that does not apply to European populations is that African-Americans are more likely to live in urban than in rural areas of the US, and have higher rates of asthma even after controlling for covariates such as socioeconomic status, place of residence, and income level. Thus, higher asthma prevalence in the urban US may be confounded by the disproportionate distribution of African-Americans in urban areas.

The suggestion that asthma prevalence may be lower in rural regions of the United States is not tantamount to stating that asthma is not an important public health concern in rural communities. Rural patients with asthma face difficult challenges including limited access to general medical care and poor access to specialized and urgent medical services, and there is limited data that they may in fact have a higher burden of asthma hospitalizations than others. Large scale interventions to reduce morbidity and mortality among rural patients with asthma in the US have not been designed or implemented, despite rural Americans representing one of the most highly disadvantaged populations in the US.

Future Directions

The rural experience with asthma in the United States is insufficiently studied, and there are several areas that would benefit from further work. First, there are currently no peer reviewed studies analyzing national asthma prevalence data sets to develop good estimates of nationwide

rural versus urban asthma prevalence, morbidity, and mortality, including accounting for the racial and socioeconomic covariates present in the United States. Secondly, there are no studies comparing endotoxin levels in urban and rural homes in the United States to assess the relevance of this issue to differences in American urban versus rural asthma prevalence. Finally, if rural Americans with asthma indeed represent a group suffering disproportionate asthma morbidity, there is little data to suggest which potential interventions (expanding government insurance programs upon which rural Americans disproportionately rely, expanding transportation services for rural Americans, increasing incentives for primary and particularly specialist physicians to serve rural areas, providing telemedicine services to rural Americans) would be most effective.

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Abbreviations

OR	odds ratio
CI	confidence interval
ISAAC	International Study of Asthma and Allergies in Childhood
SMSA	Standard Metropolitan Statistical Area

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Figure 1.

Yearly asthma hospitalization rate and poverty level by county in Tennessee. This bubble plot shows asthma hospitalization rates for residents of each county, obtained from a Tennessee Department of Health asthma report,⁶⁴ plotted against the percent of county residents below the federal poverty level.⁶⁶ Each bubble (circle with a central dot) represents one of the 95 counties in Tennessee, and the size of the circle represents county population⁶⁶ (the largest green circle is Shelby County [Memphis], the second largest Davidson County [Nashville], and so forth). The green circles are urban central counties within Standard Metropolitan Statistical Areas (by current Office of Management and Budget definition,^{reference 65}). The red circles are non-central counties within the SMSAs (titled “SMSA” in the legend). The blue

circles are rural counties. The plot shows that rural counties in Tennessee face higher burdens both of poverty and of asthma hospitalization.