
Asthma in rural America

Dennis R. Ownby, MD

Objectives: To examine current trends of asthma prevalence, diagnosis, and utilization of care in rural areas, increase awareness about asthma disease burden, and provide general recommendations for improving care in this setting.

Data Sources: MEDLINE searches were conducted for articles published from 1966 onward, with human subjects and the English language as descriptors. Other terms used included *undiagnosed frequent wheezing*, *hygiene hypothesis*, *atopic sensitization*, *endotoxin*, *telemedicine*, and *asthma prevalence and care in rural or urban areas*.

Study Selection: Review and original research studies that reported on asthma care in rural areas were selected for evaluation.

Results: Contrary to common belief, evidence suggests that asthma prevalence of rural and urban youth is comparable in the United States and may indeed be higher in rural areas. Data are not available to determine prevalence rates for rural adults in the United States. This review presents data suggesting that the utilization of asthma care among rural and urban residents may not be comparable. Rural residents are confronted with certain barriers to care that are not as common in the urban setting. These include lack of health care insurance, geographic obstacles to obtaining care, inability of getting suitable appointments, scarcity of health care professionals, and poor access to information about asthma.

Conclusions: Current literature suggests that asthma in rural areas may be underdiagnosed and deserves additional study. Improving formal and continuing education of health care professionals, compensating for health care shortages by using existing resources, and facilitating patient support and education are some of the ways to address the special needs faced by rural residents.

Ann Allergy Asthma Immunol. 2005;95(Suppl 2):S17–S22.

INTRODUCTION

Current estimates of asthma prevalence in rural America may be misleading because of a lack of studies that examine the existing situation in those areas. In fact, results from a MEDLINE survey show that of 293 references found when searching the term *asthma* between 1966 and 2004, 106 (53%) of the 200 references directly related to urban asthma were conducted in the United States, whereas only 16 (15%) of 80 studies directly related to rural asthma during the same period were conducted in the United States. These numbers reflect an existing bias toward conducting studies in urban areas both in the United States and abroad. The locations of most medical schools, ease of gathering a large number of patients, and ease of contacting those patients are some of the reasons presumably behind this trend. Parallel to this observation is the notion that most rural environments are agricultural. On the contrary, in many areas of the United States, agriculture has become a large business, and people living in rural areas are not necessarily in traditional farm environments.

Another general misconception exists surrounding the hygiene hypothesis. Coined in 1989 by David Strachan, the hygiene hypothesis states that increased exposure to microbial components and increased prevalence of naturally occurring infections, such as those acquired among siblings in large families, may modulate the immune system to provide subsequent protection against asthma, allergies, and autoim-

mune diseases.^{1,2} Thus, less hygienic environments, presumably such as rural areas, may be beneficial in decreasing the incidence of asthma. However, although some studies confirm a protective effect derived from growing up on a farm, most children in rural America do not live on farms.^{2–6}

Likewise, the question of undiagnosed asthma prevalence is multifaceted, with consequences that affect the social and economic aspects of the disease. Studies show that people in rural areas are less likely to receive appropriate controller medications, such as inhaled corticosteroids, than people in urban areas; they are also less likely to see an asthma specialist and to receive community support.^{7,8} Rural residents also have less access to health care professionals than urban residents, face less continuity of care, have less access to educational materials, tend to experience more poverty, and are less likely to be insured.^{9–15} Furthermore, rural areas generally have a shortage of health care professionals and tend to have less training and fewer educational resources available.^{16–20} All of these factors highlight a need for improving asthma care in rural areas.

This review examines current trends in rural asthma prevalence, diagnosis, and utilization of care in the United States. In addition, it addresses the socioeconomic burden of asthma and provides general recommendations toward improving asthma care in rural areas. MEDLINE searches were conducted from 1966 onward, with human subjects and the English language as descriptors. Other terms used included *undiagnosed frequent wheezing*, *hygiene hypothesis*, *atopic sensitization*, *endotoxin*, *telemedicine*, and *asthma prevalence and care in rural or urban areas*. Review and original

Department of Pediatrics, Medical College of Georgia, Augusta, Georgia.

Received for publication June 8, 2004.

Accepted for publication in revised form December 13, 2004.

research studies that reported on asthma care in rural areas were selected for evaluation.

ASTHMA PREVALENCE IN RURAL AREAS

It is generally believed that asthma is less prevalent in rural areas than in urban areas, possibly due to the hygiene hypothesis; however, evidence exists that may argue against this. Statewide studies in the United States have found that children and adolescents who live in rural areas have a higher prevalence of asthma than their urban counterparts. In a study of 554,105 children aged 0 to 14 years enrolled in the North Carolina Medicaid program during 1997 to 1998, Buescher and Jones-Vessey²¹ reported that 69,289 children (12.5%) were diagnosed as having or had received a prescription drug for asthma. Of those, the prevalence was higher in rural children compared with urban children (13.3% [47,906 of 359,748 participants] and 11% [21,383 of 194,357 participants], respectively). Although the study's authors did not calculate the statistical significance of this difference, a statistical analysis of the data showed that the between-group difference was statistically significant ($P < .001$). When interpreting these data, however, it is important to note that this study made use of both diagnosis and prescription information for estimates of asthma prevalence. The study's authors suggested a possible overestimation of the asthma cases when the drugs prescribed were used in addition to diagnoses, but this presumably would affect the prevalence equally in rural and urban areas.²¹

Asthma underdiagnosis in rural areas has been reported in other studies, and contradictory reports of independent risk factors that may be associated with this apparent underdiagnosis have been surfacing in recent years.^{22–24} For example, epidemiologic research of pediatric asthma in the United States has been largely based on physician diagnosis or parental-reported diagnosis.^{22,25,26} However, it has been shown that using diagnosis parameters alone may underestimate the true prevalence of asthma²³ and, by definition, the diagnostic umbrella should encompass not only prevalence of morbidity but also other important factors, such as symptom perceptions, physician practice, and access to care.²⁷

Another possible factor that has been suggested to contribute to underdiagnosis of asthma is that frequent wheezing among rural residents may in fact be undiagnosed asthma. The North Carolina School Asthma Survey conducted from 1999 to 2000 by Yeatts et al²⁴ made use of an adapted International Survey of Asthma and Allergies in Childhood (ISAAC) questionnaire to determine the prevalence of undiagnosed frequent wheezing and related risk factors. The questionnaire was adapted using written- and video-symptom questions, but it was not validated in this study because of budgetary constraints. However, in other studies, the ISAAC method of video-guided, adolescent self-reporting of asthma has been found consistent with parental reporting and physician diagnosis of asthma.^{28–30}

The survey evaluated 122,829 children aged 12 to 18 years from 499 public middle schools in North Carolina. Of those,

a total of 7,587 children with frequent wheezing, 12,174 asthmatic patients, 64,644 asymptomatic children, and 38,424 children with mild asthma-like symptoms were identified. Significantly more children reporting frequent wheezing lived in rural areas (56%) than in urban areas (44%) ($P < .001$). Similarly, more children with diagnosed asthma lived in rural areas (51%) than in urban areas (49%) ($P < .001$). Asymptomatic children were equally likely to live in rural or urban areas.²⁴

Overall, 70% of children with frequent wheezing and 86% of asthmatic patients reported having allergies (defined as any allergy to cat, dog, grass, pollen, or dust) vs 36% of asymptomatic patients ($P < .001$).²⁴ A higher proportion of children with frequent wheezing also reported poor health (23%) compared with the asthmatic and asymptomatic groups (20% and 4%, respectively) ($P < .001$). Additionally, 88% of children with frequent wheezing and 99% of asymptomatic children never used an inhaler vs 22% of asthmatic patients ($P < .001$). Thus, the frequent wheezing group was almost as likely to have allergies as the diagnosed asthmatic group. Furthermore, they were more likely to feel that they had poor health and less likely to have been prescribed an inhaler.

The study investigators interpreted these findings as strongly suggestive that patients with frequent wheezing have undiagnosed asthma.²⁴ Thus, this study may prove that frequent wheezing is more common in rural areas, which would result in an underestimation of asthma prevalence in those areas. However, as stated herein, since the ISAAC questionnaire was not validated in this study, additional research is needed to corroborate these results, particularly because mixed reports regarding the utility of the questionnaire have been reported.^{28–32}

ENVIRONMENTAL EXPOSURE IN RURAL AREAS: A CONFERRED BENEFIT?

Environmental exposure to microbial components, as stated by the hygiene hypothesis, is theorized to play an important role during the maturation of the immune system, triggering the development of tolerance to one's environment. Certain European farm environments have been noted to confer a protective effect against allergic diseases.^{3–5,33} However, although protective, this effect is complex in nature, and it seems to be correlated with a temporal element (eg, exposure during the first year of life), stimulus intensity (eg, dose and frequency), other concurrent exposures, and genetic variability in immune response to endotoxin.^{2,34}

In a cross-sectional study of 812 children from 319 farming and 493 nonfarming families in Austria, Germany, and Switzerland, Riedler et al³ showed that exposure to stables in combination with consumption of farm milk by children younger than 1 year decreased the frequency of asthma, hay fever, and atopic sensitization to 1% (3/218), 3% (7/218), and 12% (27/218), respectively, from 12% (20/170), 16% (27/170), and 33% (56/170), respectively, observed in children from nonfarming families. These effects were less pro-

nounced for children exposed to stables only (6% [3/48], 4% [2/48], and 21% [10/48] for asthma, hay fever, and atopic sensitization prevalence, respectively) or for those who consumed farm milk only (6% [11/189], 4% [8/189], and 15% [29/189] for asthma, hay fever, and atopic sensitization prevalence, respectively). In children older than 1 year, the observed effects dissipated with time. Hence, the conferred benefits were most beneficial in children exposed to a farming environment before the age of 1 year.³

Evidence suggests that endotoxin, a cell-wall component of gram-negative bacteria, and other microbial components are partially responsible for regulating different processes within the immune system. For example, endotoxin increases the production of interleukin 10 and interferon- γ .³ Braun-Fahrlander et al⁴ demonstrated that endotoxin levels in samples of dust derived from children's mattresses were inversely proportional to the incidence of hay fever, atopic asthma, and atopic sensitization. Mattress endotoxin levels were found to be significantly higher for children from farming households (37.8 U/mg of dust) compared with those of children from nonfarming households (22.8 U/mg of dust) ($P < .001$).

In the same study, children from farming households were found to have a lower prevalence of hay fever (4.1%), atopic sensitization (17.2%), and atopic asthma (3.1%) compared with children from nonfarming households (10.5% [$P < .001$], 23.5% [$P < .03$], and 5.9% [$P < .07$], respectively). Similarly, in children from nonfarming environments, the incidence of atopic wheezing and atopic asthma decreased with increasing levels of mattress endotoxin; however, it was also shown that increasing levels of mattress endotoxin in this subgroup of patients was directly proportional to increasing prevalence of nonatopic wheezing and asthma. Overall, exposure to a farming environment during the first year of life had an inverse relationship with all these conditions, including nonatopic wheezing and asthma, regardless of the level of endotoxin exposure. Authors associated this long-term exposure to endotoxins with a down-regulation of response and thus protection against these allergic conditions.⁴

Early childhood exposure to endotoxin was likewise found to correlate with decreased incidence of atopic disease in birth cohort studies.² Gehring et al³⁵ found that endotoxin exposure during the first 6 months of life significantly reduced the risk of atopic eczema (odds ratio [OR], 0.50; 95% confidence interval [CI], 0.28–0.88). The study comprised data from 1,884 normal-weight neonates, with mattress dust samples collected from mothers and children at 3 months after birth. Results also showed, however, that endotoxin levels were correlated with an increased risk of respiratory infections (OR, 1.69; 95% CI, 1.25–2.28); cough with respiratory infection, bronchitis, or both (OR, 1.73; 95% CI, 1.28–2.33); and wheezing (OR, 2.37; 95% CI, 1.40–4.03). Although these studies provide evidence in support of the hygiene hypothesis, they do not support a clear therapeutic course of action, warranting the need for future studies in this area of research.^{2,6}

PATTERNS OF ASTHMA DIAGNOSIS AND UTILIZATION OF CARE IN RURAL AREAS

Diagnosis

As previously mentioned, some statewide studies provide evidence to suggest that asthma prevalence in children and adolescents in rural areas is at least as high as that in urban areas.²¹ Furthermore, other studies suggest that incidence of undiagnosed recurrent wheezing may be a more common phenomenon among rural vs urban residents.²⁴ In a study of Tennessee children aged 2 to 17 years enrolled in Medicaid, only 44.8% of the 6,035 children had a prescription filled for oral corticosteroids within 7 days after an emergency department visit for asthma, and only 55.5% of 2,102 had an oral corticosteroid prescription filled after hospitalization for asthma.⁷

In the Tennessee study, older age, black race, and rural residence were each found to be independently associated with not having a prescription filled. In fact, only 39% of rural children had a prescription filled following an emergency department visit, and only 50.5% of rural children had a corticosteroid prescription filled following a hospital visit for asthma, compared with 49.4% and 60.3%, respectively, for children living in urban areas ($P < .001$). The authors suggested that these differences may be due to poorer information dissemination in rural areas, which in turn may translate to less advanced asthma care and a lower level of physician compliance with asthma guidelines.^{7,36} Furthermore, it has been suggested that the dissemination of continuing medical education may vary between rural and urban regions, leading to differences in familiarity with treatment guidelines.^{20,36} In an educational needs evaluation questionnaire sent to 1,096 rural family physicians, Norris et al²⁰ found that more than 40% of 63 items available for analysis were rated as inadequate preparation for rural practice. *Chronic childhood problems* was one of the items listed as having inadequate preparation in rural practice.

Inadequate training of health care personnel was also noted in a study of emergency service agencies in New Mexico. A questionnaire disseminated more than 3 years to those agencies revealed that only 4% and 23% of survey participants administered steroids and β_2 -agonists, respectively. Furthermore, administration of β_2 -agonists was allowed to be conducted only by those with at least a minimum of intermediate-level training.¹⁶ In a separate survey that involved school nurses from all counties in Maryland and Washington, DC, it was shown that rural nurses used peak flow meters less frequently to measure and monitor asthma severity, asked for fewer asthma referrals, and had less access to educational materials for asthma.¹⁷ Additionally, they offered less asthma education compared with other school nurses. Lack of asthma education is also a cause of concern among asthmatic patients. In a pretest and posttest telephone survey, parents of asthmatic children expressed a need for asthma educational materials, including relevant information about asthma medications.¹¹

Other factors that may contribute to underdiagnosis of asthma in rural areas include limited transportation to specialist centers, which contributes to limited access to health care professionals, a low level of referral from primary care physicians to asthma specialists, and longer distances to emergency department centers compared with urban areas.

Utilization of Care

Hospitalization rates for children with asthma have been on the rise in recent years, and as a result, discharge with a diagnosis of asthma has become the most common inpatient diagnosis in children.³⁷ Discrepancies in utilization of care among urban and rural areas have been noted to exist.^{8,10,12–15,19,20} In a study by Yawn et al,⁸ 8,634 Kentucky children aged 0 to 18 years receiving Medicaid were classified as having asthma if they had 1 or more asthma-related visits to the physician. More than 50% of these children were younger than 6 years. Urban children were twice as likely to visit an asthma specialist, 2.7 times more likely to receive care in an emergency department, and 1.4 times more likely to be prescribed oral steroids compared with rural children (5% vs 2.5% [$P < .05$], 19% vs 7% [$P < .01$], and 16% vs 12% [$P = .04$], respectively). The authors acknowledged that these data do not corroborate a disparity in asthma care among rural and urban asthmatic children; however, the data suggest that asthma in all children continues to be treated as an acute rather than chronic condition.⁸

In a recent study, Fredrickson et al⁹ evaluated billing data and focus groups to determine the cause behind frequent emergency department use by asthmatic children insured by Medicaid living in rural areas and 23 towns in Kansas. Of the 2,767 children insured by Medicaid, a total of 416 asthma-related billing events were found. Emergency department visits were noted in 196 of those events or 770 per 10,000 insured children. Two or more emergency department visits were observed in 34 children, which represented 49% of the total number of asthma-related emergency department visits. Likewise, 15 children had 3 or more emergency department visits, accounting for 29% of all emergency department visits. The focus group for the study consisted of mothers of 6 children with 1 or more hospitalizations or a minimum of 3 emergency department visits for asthma. Several factors were identified as deterrents to using primary care for asthma management, including an inability to get urgent or suitable appointments, reduced continuity of care, obstacles to after-hours coverage, and lack of attention to preventive measures, among others.⁹

Lack of access to care in rural areas is a major obstacle to overall asthma management. An estimated 8 million rural residents are believed to lack health insurance, of whom 26.5% are children. Furthermore, 18% of all farm families do not have health insurance.³⁸ In patients with asthma, mortality rates are directly correlated with the distance to the hospital,

such that geographic barriers may impose a real threat among this population group.³⁹ Another obstacle that faces patients with asthma in rural areas is the shortage of health care professionals (including primary care physicians)^{19,20} paired with a declining number of rural hospitals.⁴⁰ When compared with national averages, health care professionals of all specialties were found to be fewer in rural areas.¹⁸

The overall picture of utilization of care among asthmatic patients in rural areas is further complicated by the fact that they tend to have an overall poorer health status, with greater infant and maternal mortality rates, greater injury rates, and greater frequency of chronic conditions.^{15,41,42} Additionally, rural areas tend to have more elderly and young residents, and rural asthmatic patients are subject to longer travel distances for health care services, less public transportation, and fewer health care facilities and personnel per capita.^{13,15}

CONCLUSIONS

In summary, asthma prevalence in rural children and adolescents is comparable to that found in urban counterparts and may indeed be underestimated, contrary to what is commonly believed. Insufficient data are available to determine whether discrepancies in the prevalence of adults with asthma exist among rural and urban communities in the United States.

The literature reviewed in this article highlights the fact that differences in utilization and access to asthma care between rural and urban areas probably exist and that there are a number of factors particular to rural areas that contribute to this discrepancy. Educational programs and training materials that target the needs of all health care professionals through both formal education and continuing education may be beneficial in addressing some of the limitations discussed in this article.^{14,16,17} This may in turn help recruit and retain well-trained health care professionals in rural areas, thus aiding the diagnosis, treatment, and overall management of patients with asthma in those areas.²⁰

Another plausible option would be to use the health care professionals who are available to compensate for the shortages, for instance, increasing use of pharmacists when physicians are not available. This may increase health care access for patients.¹⁸ Providing community support for patient education of asthma care may facilitate improved care and compliance.¹¹ Other ways to change the current situation in rural areas include supplying rural clinics with asthma specialists, offering telemedicine care by asthma specialists, and improving public transportation systems. Finally, as a result of the paucity of data that examine the rural component of asthma, further research is needed to fully elucidate and address the issues specific to asthma care in those communities and the special needs that face their residents.

REFERENCES

- Strachan DP. Hay fever, hygiene, and household size. *BMJ*. 1989;299:1259–1260.
- Liu AH, Murphy JR. Hygiene hypothesis: fact or fiction? *J Allergy Clin Immunol*. 2003;111:471–478.
- Riedler J, Braun-Fahrlander C, Eder W, et al. Exposure to farming in early life and development of asthma and allergy: a cross-sectional survey. *Lancet*. 2001;358:1129–1133.
- Braun-Fahrlander C, Riedler J, Herz U, et al. Environmental exposure to endotoxin and its relation to asthma in school-age children. *N Engl J Med*. 2002;347:869–877.
- Lauener RP, Birchler T, Adamski J, et al. Expression of CD14 and toll-like receptor 2 in farmers' and non-farmers' children. *Lancet*. 2002;360:465–466.
- Eder W, von Mutius E. Hygiene hypothesis and endotoxin: what is the evidence? *Curr Opin Allergy Clin Immunol*. 2004;4:113–117.
- Cooper WO, Hickson GB. Corticosteroid prescription filling for children covered by Medicaid following an emergency department visit or a hospitalization for asthma. *Arch Pediatr Adolesc Med*. 2001;155:1111–1115.
- Yawn BP, Mainous AG III, Love MM, Hueston W. Do rural and urban children have comparable asthma care utilization? *J Rural Health*. 2001;17:32–39.
- Fredrickson DD, Molgaard CA, Dismuke SE, et al. Understanding frequent emergency room use by Medicaid-insured children with asthma: a combined quantitative and qualitative study. *J Am Board Fam Pract*. 2004;17:96–100.
- Schwartz DA. Etiology and pathogenesis of airway disease in children and adults from rural communities. *Environ Health Perspect*. 1999;107(suppl 3):393–401.
- Resto M, Huss K, Winkelstein M, et al. Asthma education in rural communities. *Clin Excell Nurse Pract*. 2001;5:168–174.
- Saywell RM Jr, Zollinger TW, Schafer ME, et al. Children with special health care needs program: urban/rural comparisons. *J Rural Health*. 1993;9:314–325.
- Hersh A, Van Hook R. A research agenda for rural health services. *Health Serv Res*. 1989;23:1053–1064.
- Hicks LL. Availability and accessibility of rural health care. *J Rural Health*. 1990;6:485–505.
- Hanson CM. The 1990s and beyond: determining the need for community health and primary care nurses for rural populations. *J Rural Health*. 1991;7(4 suppl):413–426.
- Crago S, Coors L, Lapidus JA, et al. Prehospital treatment of acute asthma in a rural state. *Ann Allergy Asthma Immunol*. 1998;81:322–325.
- Huss K, Winkelstein M, Calabrese B, et al. Rural school nurses' asthma education needs. *J Asthma*. 2001;38:253–260.
- Knapp KK, Paavola FG, Maine LL, et al. Availability of primary care providers and pharmacists in the united states. *J Am Pharm Assoc (Wash)*. 1999;39:127–135.
- Council on Graduate Medical Education. *Recommendations to Improve Access to Health Care Through Physician Workforce Reform: Fourth Report to Congress and the Department of Health and Human Services Secretary*. Rockville, MD: US Dept of Health and Human Services, Public Health Service, Health Resources and Services Administration; 1994.
- Norris TE, Coombs JB, Carline J. An educational needs assessment of rural family physicians. *J Am Board Fam Pract*. 1996;9:86–93.
- Buescher PA, Jones-Vessey K. Using Medicaid data to estimate state- and county-level prevalence of asthma among low-income children. *Matern Child Health J*. 1999;3:211–216.
- Crain EF, Weiss KB, Bijur PE, et al. An estimate of the prevalence of asthma and wheezing among inner-city children. *Pediatrics*. 1994;94:356–362.
- Silver EJ, Crain EF, Weiss KB. Burden of wheezing illness among U.S. children reported by parents not to have asthma. *J Asthma*. 1998;35:437–443.
- Yeatts K, Davis KJ, Sotir M, et al. Who gets diagnosed with asthma? frequent wheeze among adolescents with and without a diagnosis of asthma. *Pediatrics*. 2003;111(5 pt 1):1046–1054.
- Schwartz J, Gold D, Dockery DW, et al. Predictors of asthma and persistent wheeze in a national sample of children in the united states: association with social class, perinatal events, and race. *Am Rev Respir Dis*. 1990;142:555–562.
- Gold DR, Rotnitzky A, Damokosh AI, et al. Race and gender differences in respiratory illness prevalence and their relationship to environmental exposures in children 7 to 14 years of age. *Am Rev Respir Dis*. 1993;148:10–18.
- Pearce N, Douwes J, Beasley R. The rise and rise of asthma: a new paradigm for the new millennium? *J Epidemiol Biostat*. 2000;5:5–16.
- Fuso L, de Rosa M, Corbo GM, et al. Repeatability of the ISAAC video questionnaire and its accuracy against a clinical diagnosis of asthma. *Respir Med*. 2000;94:397–403.
- Beasley R, Lai CK, Crane J, Pearce N. The video questionnaire: one approach to the identification of the asthmatic phenotype. *Clin Exp Allergy*. 1998;28(suppl 1):8–12, discussion 32–36.
- Renzone E, Forastiere F, Biggeri A, et al. Differences in parental- and self-report of asthma, rhinitis and eczema among Italian adolescents: Sidria collaborative group: Studi italiani sui disordini respiratori dell'infanzia e l'ambiente. *Eur Respir J*. 1999;14:597–604.
- Ortega AN, Gergen PJ, Paltiel AD, et al. Impact of site of care, race, and Hispanic ethnicity on medication use for childhood asthma. *Pediatrics*. 2002;109(1):E1.
- Gruchalla RS, Gan V, Roy L, et al. Results of an inner-city school-based asthma and allergy screening pilot study: a combined approach using written questionnaires and step testing. *Ann Allergy Asthma Immunol*. 2003;90:491–499.
- Nilsson L, Castor O, Lofman O, et al. Allergic disease in teenagers in relation to urban or rural residence at various stages of childhood. *Allergy*. 1999;54:716–721.
- Liu AH. Endotoxin exposure in allergy and asthma: reconciling a paradox. *J Allergy Clin Immunol*. 2002;109:379–392.
- Gehring U, Bolte G, Borte M, et al. Exposure to endotoxin decreases the risk of atopic eczema in infancy: a cohort study. *J Allergy Clin Immunol*. 2001;108:847–854.
- Cabana MD, Ebel BE, Cooper-Patrick L, et al. Barriers pediatricians face when using asthma practice guidelines. *Arch Pediatr Adolesc Med*. 2000;154:685–693.
- Gergen PJ, Weiss KB. Changing patterns of asthma hospitalization among children: 1979 to 1987. *JAMA*. 1990;264:1688–1692.
- US Senate Testimony on Rural Health Before the Senate Subcommittee on Labor, Health and Education Appropriations. (1993) (testimony of P. Lee).
- Jones AP, Bentham G. Health service accessibility and deaths

-
- from asthma in 401 local authority districts in England and Wales, 1988–92. *Thorax*. 1997;52:218–222.
40. Gordon R, Meister J, Hughes R. Accounting for shortages of rural physicians: push and pull factors source. In: Gesler W, Ricketts T, eds. *Health in Rural North America: The Geography of Health Care Services and Delivery*. New Brunswick, NJ: Rutgers University Press; 1992.
41. Coward RT, Miller MK, Dwyer JW. Rural America in the 1980s: a context for rural health research. *J Rural Health*. 1990;6:357–363.
42. Norton CH, McManus MA. Background tables on demographic

characteristics, health status, and health services utilization. *Health Serv Res*. 1989;23:725–756.

Requests for reprints should be addressed to:
Dennis R Ownby, MD
Department of Pediatrics
Medical College of Georgia
1120 15th St
Suite BG1009
Augusta, GA 30912
E-mail: downby@mail.mcg.edu