Asthma prevalence and morbidity among rural Iowa schoolchildren

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Background: There are conflicting findings about the prevalence of asthma among farm and nonfarm children.
Objectives: We sought to estimate asthma prevalence and morbidity and determine differences between farm and nonfarm children.
Methods: The study population consisted of all children aged 6 to 14 years enrolled in 10 school districts in 2 noncontiguous rural Iowa counties from 2000 through 2002. The mailed parental screening questionnaire included the International Study of Asthma and Allergies in Childhood core questionnaire, items from the Functional Severity Index, and items on physician diagnosis and medication and urgent care use.
Results: The response rate was 86.6%. The 12-month prevalence of wheeze was 19.1%. Self-reported physician diagnosis of asthma was reported by 13.4%. On multivariable analysis controlling for age, sex, and county, children who lived on farms were less likely than those who lived in town to have ever wheezed (odds ratio, 0.71; 95% CI, 0.58-0.87) or to have wheezed during the past year (odds ratio, 0.77; 95% CI, 0.60-0.98). However, this protective association with farming was only observed in one of the study counties. Among those who wheezed, farm and nonfarm children were equally likely to have been given a diagnosis of asthma and had comparable morbidity.
Conclusion: By using a standardized questionnaire with a high response rate in this large, rural, population-based study, asthma prevalence rivaled that in large Midwestern cities. Unmeasured risk factors might account for the apparent protective effect in Keokuk County. These findings cast doubt on a protective effect of rural life for the development of childhood asthma. (J Allergy Clin Immunol 2004;113:66-71.)

Key words: *Asthma, children, screening, rural, farm*

Abbreviation used
ISAAC: International Study of Asthma and Allergies in Childhood

The International Study of Asthma and Allergies in Childhood (ISAAC) developed a questionnaire for measuring asthma prevalence across countries.[1] ISAAC phase 1 estimates of childhood asthma prevalence have been published for over 50 countries.[2] Marked variation (up to 15-fold) was found among countries, and this has sparked renewed energy in the pursuit of environmental factors that might be associated with asthma development or exacerbation. Now that the ISAAC questionnaire has provided the standardization needed for cross-area prevalence comparisons, it is increasingly important to apply this measure to new populations to expand the reference database. ISAAC-based prevalence estimates for population-based rural US samples have not been previously reported.

It has been noted that rural environmental factors might be associated with differences in asthma prevalence or morbidity. Some reports have suggested a lower frequency of asthma among children who live on a farm,[3,4] whereas studies among adults have found farming to be a consistent risk factor for occupational asthma.[5,6] Rural environmental factors include exposure to pro-inflammatory substances, allergens, and direct airway irritants (eg, endotoxins, glucans, bioaerosols, storage mites, animal allergens, and agricultural chemicals).[7]

Although it is less clear whether asthma is more common among rural children than among urban children, it is clear that asthma among rural children interacts with unique social and health care environments found in the rural setting. Those who live in rural areas have lower mean incomes and lower access to health care,[8] and mortality rates from asthma might be higher.[9] A study among Iowa school nurses in 92 communities found that 108 of 109 school nurses identified asthma as the most frequently occurring chronic condition among children for whom they cared.[10] School-based screening for asthma has been advocated as an efficient method for improving asthma outcomes by identifying children with asthma and for facilitating the connection of families with medical care.[11]

The objectives of the present study were to estimate asthma prevalence and morbidity in 2 rural Iowa counties and to estimate whether children who live on a farm have different asthma prevalences and morbidities than do their schoolmates from the same rural areas who do not live on a farm. The school-based asthma screening was conducted in preparation for a community-based intervention study (the Rural Childhood Asthma Study). The

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parent-reported lifetime prevalence of physician-diagnosed asthma among a sample of children from the study communities had been previously estimated in the Keokuk County Rural Health Study to be 16.7%.

METHODS

The study was approved by the Institutional Review Board of the University of Iowa. The study sample was all children aged 6 to 14 years who were enrolled in one of 10 school districts in either of 2 noncontiguous rural Iowa counties during the academic years 1999-2000, 2000-2001, and 2001-2002. The 2 counties were selected because of their close similarity in agricultural production. Screening was conducted during 3 separate time periods, each consisting of approximately equal numbers of children from each county. Screening was conducted for group 1 (2 school districts) during January and February 2000, for group 2 (6 school districts) during October and November 2000, and for group 3 (2 school districts) during March through June 2002. The screening questionnaire was mailed to all students with a cover letter from the school principal and the superintendent of schools from the school district. A postcard was sent if a response was not received within 3 weeks. Nonresponders received a second mailed questionnaire 3 weeks later. Telephone calls were made to those who did not respond to any of the mailings. Of 3567 names on the school rosters for the 10 included school districts, a total of 3090 (86.6%) completed the screening questionnaire. Approximately two thirds (n = 2091) of responders completed the mailed screening questionnaire, and one third (n = 999) completed the questionnaire by telephone.

The questionnaire included demographic characteristics and asthma symptoms. Demographic characteristics were age, sex, whether the family lived in the town or the country, and, if in the country, whether they lived on a farm or in a rural home. Asthma prevalence and morbidity measures included the ISAAC core questionnaire,[1] 2 items on activity limitations in the past year and 1 on troublesome morning symptoms in the past year from the Functional Severity Index,[12] 1 item on physician diagnosis ("Has a doctor ever told you that your child has asthma?"), 1 item on whether medications had been used for wheezing in the past year, and items on health care use in the past year (emergency department/hospital use and frequency of use of a rescue inhaler, puffer, or nebulizer). Children were defined as having had "frequent symptoms" in the past year if they had activities limited by cough or wheeze or shortness of breath at least monthly, troublesome wheezing first thing in the morning at least once per week, sleep disturbed because of wheezing or cough more than 2 nights per month, or use of a rescue inhaler, puffer, or nebulizer at least once per week. Children were defined as having had "severe symptoms" in the past year if wheezing had limited the child's speech to only 1 or 2 words between breaths or if the child had any visits to the emergency department or hospitalizations because of asthma, bronchospasm, or wheezing.

Statistical analysis

Seven multivariable logistic regression analyses of the association of farm residence with asthma prevalence and morbidity were conducted. Four models included all respondents, and the dependent variable was one of the following: wheezing ever versus never wheezing; physician diagnosis (yes/no); wheeze in the last 12 months (yes/no); and either physician diagnosis or wheeze in the last 12 months (yes/no). The intent of these 4 models was to contrast the 4 overall prevalence measures. Three models were estimated only among those who had wheezed in the last 12 months and had the following dependent variables: (1) having a physician diagnosis; (2) having severe symptoms in the last 12 months versus not having severe symptoms; and (3) having frequent symptoms versus not having frequent symptoms in the last 12 months. The intent of these models was to evaluate differences in asthma diagnosis and morbidity while controlling for asthma prevalence. To examine the possibility of underdiagnosis and suboptimal management, respectively, sensitivity and positive predictive values of asthma prevalence items were calculated with respect to the ability to identify children with parent-reported frequent or severe symptoms.

TABLE I. Characteristics of study subjects (n = 3090)

	N (%)
Residence	
Farm	641/3055 (21.0)
Rural home	774/3055 (24.4)
Town	1667/3055 (54.6)
Sex	
Female	1524/3090 (49.3)
Male	1566/3090 (50.7)
Age (y)	
6-9	1417/3090 (45.8)
10-14	1673/3090 (54.2)
Lifetime prevalence measures	
Wheeze ever	956/3090 (30.9)
Asthma ever	403/3090 (13.0)
Physician ever told you child has asthma	414/3090 (13.4)
Prevalence in past year	
Wheeze	590/3090 (19.1)
Exercise wheeze	372/3090 (12.0)
Dry cough at night	547/3090 (17.7)
Symptoms in the past year among those who ever wheezed	
Wheeze attacks	
None	485/956 (50.7)
1-3	297/956 (31.1)
>3	174/956 (28.2)
Nocturnal wheeze	
Never	645/956 (67.5)
≤2 nights/mo	226/956 (23.6)
>2 nights/mo	85/956 (8.9)
Speech-limiting wheeze	90/956 (9.4)
Used medications for wheezing	347/956 (36.3)
Frequent symptoms*	345/956 (36.1)
Severe symptoms*	146/956 (15.3)

*Children were defined as having had "severe symptoms" in the past year if wheezing had limited the child's speech to only 1 or 2 words between breaths or if the child had any visits to the emergency department or hospitalizations because of asthma, bronchospasm, or wheezing. Children were defined as having had "frequent symptoms" in the past year if they had activities limited by cough or wheeze or shortness of breath at least monthly, troublesome wheezing first thing in the morning at least once per week, sleep disturbed because of wheeze or cough more than 2 nights per month, or use of a rescue inhaler, puffer, or nebulizer at least once per week.

RESULTS

The study population is described in Table I. The lifetime prevalence of wheeze was 30.9%. Wheezing in the past year was reported by 19.1%. A physician diagnosis of asthma was reported by 13.4%. Among those who had ever wheezed, more than a third reported frequent symptoms, and 15.3% reported severe symptoms in the past year.

Multivariable analyses are displayed in Table II. Results of stratified analyses and tests for county by residence–type interactions (*P* values between .07 and .26) indicated that county-specific analyses should also be

TABLE II. Association of residence with asthma prevalence and morbidity, with town residents as the reference category

	Adjusted* odds ratio (95% CI)					
	Overall		Keokuk County		Louisa County	
	Rural home†	Farm†	Rural home†	Farm†	Rural home†	Farm†
Wheeze						
Wheeze ever	0.85 (0.70-1.03)	0.71 (0.58-0.87)	0.77 (0.59-1.02)	0.61 (0.47-0.79)	0.93 (0.72-1.20)	0.91 (0.55-1.27)
Current wheeze	0.87 (0.70-1.08)	0.77 (0.60-0.98)	0.82 (0.59-1.15)	0.66 (0.47-0.91)	0.92 (0.69-1.24)	0.98 (0.68-1.42)
Physician diagnosis						
Physician diagnosis	0.84 (0.65-1.09)	0.80 (0.61-1.06)	0.72 (0.48-1.08)	0.70 (0.49-1.01)	0.96 (0.69-1.35)	0.98 (0.64-1.51)
Physician diagnosis or current wheeze	0.86 (0.70-1.06)	0.77 (0.61-0.96)	0.78 (0.57-1.07)	0.68 (0.51-0.91)	0.94 (0.72-1.24)	0.94 (0.66-1.34)
Physician diagnosis (among whose with current wheeze)	0.88 (0.60-1.32)	0.95 (0.61-1.49)	0.81 (0.44-1.52)	0.88 (0.48-1.61)	0.98 (0.58-1.65)	1.15 (0.60-2.23)
Morbidity (among those with current wheeze)						
Severe‡ symptoms	1.32 (0.84-2.08)	1.34 (0.80-2.24)	0.82 (0.38-1.81)	1.35 (0.67-2.73)	1.74 (0.98-3.10)	1.32 (0.62-2.80)
Frequent§ symptoms	0.84 (0.56-1.26)	0.79 (0.50-1.24)	0.69 (0.37-1.32)	1.14 (0.62-2.11)	0.93 (0.54-1.60)	0.51 (0.26-0.99)

*Adjusted for age, sex, and county of residence.
†Reference category is town residence.
‡Children were defined as having had "severe symptoms" in the past year if wheezing had limited the child's speech to only 1 or 2 words between breaths or if the child had any visits to the emergency department or hospitalizations because of asthma, bronchospasm, or wheezing.
§Children were defined as having had "frequent symptoms" in the past year if they had activities limited by cough or wheeze or shortness of breath at least monthly, troublesome wheezing first thing in the morning at least once per week, sleep disturbed because of wheezing or cough more than 2 nights per month, or use of a rescue inhaler, puffer, or nebulizer at least once per week.

conducted. Controlling for age, sex, and county, children who lived on a farm in Keokuk County were significantly less likely to have ever wheezed and to have wheezed in the past year than were those who lived in town. Residence status was not associated with wheeze prevalence in Louisa County. Among those who had wheezed in the past year, farm residence was not associated with the probability of physician diagnosis. Also, among those who had wheezed in the past year, Louisa County residents who lived on a farm had a significantly lower probability of having frequent asthma symptoms than did those who lived in town. Those who lived in town, on a farm, or in a rural nonfarming home had comparable probability of diagnosis and presence of severe symptoms among those who wheezed.

Table III displays the concordance between asthma diagnosis and asthma symptoms. The 2 items that asked specifically about asthma ("Has your child ever had asthma? Has a physician ever told you that your child has asthma?") both had poor sensitivity: 178 (41.6%) of 428 and 102 (67.5%) of 151 for frequent symptoms and severe symptoms, respectively. This suggests the possibility of underdiagnosis in this population. In addition to underdiagnosis, the high rate of frequent or severe symptoms among those with a physician diagnosis indicates that poor asthma management among those given a diagnosis of asthma might also be important. In the 2 Iowa counties, 178 (43.0%) of 414 parents of children with a physician diagnosis reported that their child had frequent symptoms, and 102 (24.6%) reported severe symptoms (Table III).

DISCUSSION

A high response rate was obtained in this large, rural, population-based study using an internationally standardized instrument for measuring the prevalence of wheeze and asthma. We found a prevalence of wheeze or asthma comparable with that seen in Midwestern cities, thus casting doubt on a protective effect of rural living for the development of asthma. Comparing our results with those of other studies that used the ISAAC questionnaire, the 12-month prevalence of wheeze (19.1%) was comparable with that reported for 13- to 14-year-old children in the Chicago (19.8%) and Seattle (22.9%) studies that used the ISAAC questionnaire[2] and greater than that reported for inner-city elementary schools in Minneapolis (11.9%).[11] In contrast, the 12-month prevalence of wheeze was comparable with that in rural Quebec[4] (although the Quebec study was of only 12- to 18-year-old subjects) and substantially higher than that in Europe.[3,13] The 12-month prevalence of wheeze (current wheeze) was reported to be 8.3% in rural Switzerland (5.2% farm and 9.1% nonfarm)[3] and 17.1% of farm-exposed and 24.7% of nonfarm-exposed children in rural Quebec,[4] and that in rural areas of Austria, Germany, and Switzerland ranged from 3% among those exposed to stables and farm milk in the first year of life to 9% among those exposed at ages 1 to 5 years to 15% exposed to neither stables nor farm milk.[13] This study's 12-month prevalence of exercise-induced wheeze (12.0%) was much lower than that reported for 13- to 14-year-old children in Chicago (29.5%) and Seattle (28.2%). The Min-

TABLE III. Concordance between lifetime prevalence items and current asthma morbidity

Wheeze ever	Asthma ever	Physician ever told	N	With frequent activity limitations, n (%)	With ED or hospitalization, n (%)	With any frequent* asthma symptoms, n (%)	With any severe† asthma symptoms, n (%)
Y	Y	Y	365	116 (31.8)	51 (14.0)	169 (46.3)	97 (26.0)
		N	16	5 (31.2)	3 (18.8)	7 (43.8)	4 (25.0)
Y	N	Y	22	5 (23.7)	4 (18.2)	7 (31.8)	5 (22.7)
		N	553	81 (14.6)	20 (3.6)	162 (29.3)	40 (7.2)
N	Y	Y	18	1 (5.6)	0	2 (11.1)	0
		N	4	0	0	1 (25.0)	0
N	N	Y	9	0	0	0	0
		N	2103	21 (1.0)	5 (0.24)	80 (4.0)	5 (0.2)
Total			3090	229 (7.4)	83 (2.7)	428 (13.8)	151 (4.9)

ED, Emergency department.
*Children were defined as having had "frequent symptoms" in the past year if they had activities limited by cough or wheeze or shortness of breath at least monthly, troublesome wheezing first thing in the morning at least once per week, sleep disturbed because of wheezing or cough more than 2 nights per month, or use of a rescue inhaler, puffer, or nebulizer at least once per week.
†Children were defined as having had "severe symptoms" in the past year if wheezing had limited the child's speech to only 1 or 2 words between breaths or if the child had any visits to the emergency department or hospitalizations because of asthma, bronchospasm, or wheezing.

neapolis elementary school–based screening study (n = 1103)[12] was more comparable with ours in age distribution. The question "has a doctor ever told you your child has asthma" was answered positively by 13.4% in our study, which was similar to the rate reported for this item in the Minneapolis schoolchildren study (13.8%). The prevalence of ever having asthma (13.0%) was greater than that observed in rural Switzerland (9.3% total, 7.8% farm, and 9.6% nonfarm),[3] rural Quebec (5.8% farm and 8.3% nonfarm),[4] and rural Austria, Germany, and Switzerland (1% among those exposed to stables and farm milk in the first year of life to 11% among those exposed at ages 1 to 5 years to 12% among those exposed to neither stables or farm milk).[13]

After controlling for age, sex, and county, parents of children who lived on a farm were less likely to report that their child had ever wheezed than were parents of children who lived in town. Farm children were also more likely to have wheezed in the previous year than were those who lived in town. However, this protective association was only seen in one of the 2 study counties. Braun-Fahrlander et al[3] found in 3 rural communities in Switzerland that there was no significant difference in having wheezed in the past year between farm children and children living in the same rural villages but in nonfarming families. In the same study farming as a parental occupation was associated with fewer sneezing attacks during the pollen season and lower rates of atopic sensitization. In contrast, Ernst and Cormier[4] found that children living on a farm had significantly less common current wheeze, airway hyperresponsiveness, and skin test positivity to inhaled allergens than children from the same 14 schools in rural areas surrounding Quebec City who had never lived on a farm. Riedler et al[13,14] found that the prevalence of asthma, hay fever symptoms, and atopic sensitization was significantly lower in farm children than in nonfarm children in rural areas of Austria, Germany, and Switzerland. Downs et al[15] found that the prevalence of current wheeze was lower among farm children in one rural area of New South Wales, but there was no association of farm residence with current wheeze in another rural area 550 km away. Although not significant statistically because of small sample size, Wickens et al[16] found farm residence to be associated with an increased prevalence of current wheeze (adjusted odds ratio, 1.9; 95% CI, 0.7-5.6) and asthma (adjusted odds ratio, 2.0; 95% CI, 0.8-5.2).

Possible explanations for these varying findings include differences in study power, differences in control of confounders, and cross-cultural differences in farm and rural lifestyles. Of the recent studies that have addressed the association of childhood farm residence with asthma, the Iowa study included the largest number of farm families. In Switzerland the odds ratio for current wheeze in children of farm families was identical to our estimate (0.77), but the 95% CI was wider and included 1.0.[3]

The distribution of reported potential confounders varies across studies. For example, farm parents had less education than nonfarm parents in Switzerland[3] and Austria,[14] whereas in Keokuk County[17] and in New Zealand[16] farm parents had more years of education. In studies that measured environmental tobacco smoke or parental smoking,[3,14-17] farm children consistently had lower tobacco exposure. Examples of risk factors found in some studies to be more common among farm families include exposures to pets,[3,4,14,16] coal or wood heat sources,[3,16] the presence of more siblings,[4,14] and breastfeeding.[15] In addition, the number of livestock to which an individual child is exposed might vary across study sites. Residual confounding by unmeasured risk factors that vary across study sites might explain some of the differences among studies and might also explain the different findings for the 2 counties in our study.

Finally, the farming lifestyle and concepts of rurality may differ cross-culturally. Iowa is ranked number 1 in US pork production, with a census of 17 million hogs and at least 3000 registered, large, concentrated animal-feeding operations. Poultry (Iowa is ranked first in egg production) and cattle (Iowa is ranked sixth in cattle mar-

ketings) also feature prominently in Iowa livestock production. The average number of hogs per farm and the size of beef feedlots have increased over the past 30 years, mirroring a trend in the rest of the United States. In Iowa there may be little difference in environmental exposures between farm and nonfarm residents. Agricultural exposures are ubiquitous in rural Iowa communities. For the state of Iowa as a whole, 87% of the land mass is farmland. Many farm and nonfarm children have significant exposure to livestock through chores and through participating in extracurricular groups (eg, 4H, Future Farmers of America, and scouting). Corn or soybean fields frequently surround schools. Many rural towns prominently feature grain elevators in the center of town, and corn dust is visible in the air at certain times. Small rural towns are often only a few square blocks of houses surrounded by fields of corn or soybeans. The towns served by the 10 study school districts ranged in size from a population of 30 to a maximum of 2209. Only 3 of the 36 towns had a population of greater than 1000, and 17 had a population of less than 100.

In contrast, rurality and farm life in other countries may differ from the same concepts in Iowa communities. Among places considered rural, there is considerable variability across countries in population density, topography, nearness to an urban area, average farm size, farm-life behaviors, livestock concentration, and percentage of land mass farmed. For example, the volume of livestock production is lower on European farms than on those in Iowa; however, European farm houses tend to have closer proximity to the farm's livestock. In rural places where small farms are interspersed with forest or other nonfarm land uses or where farm-life behaviors and home proximity to livestock result in higher indoor concentrations of environmental exposures, gradients of exposure between farm homes and nonfarm homes might be more likely.

Asthma may be underdiagnosed in these rural communities. In the 2 counties, 13.8% of parents reported that their child had frequent symptoms (activities limited by cough or wheeze or shortness of breath at least monthly, troublesome wheezing first thing in the morning at least once per week, sleep disturbed because of wheezing or cough more than 2 nights per month, or use of a rescue inhaler, puffer, or nebulizer at least once per week; Table III). Of these, only 41.6% reported ever being given a diagnosis of asthma. Of the 4.9% with severe symptoms, 67.5% reported a physician diagnosis. Others have also reported that in spite of increasing prevalence, asthma still appears to be underdiagnosed among school-aged children.[11,18-23] These studies have documented that a significant proportion of children with asthma-like symptoms on questionnaire screening who do not have a physician diagnosis nevertheless have abnormal airway behavior[20,23] or when reviewed by a physician[11,20,22] are found to have asthma.

A high rate of frequent or severe symptoms was found among those with a physician diagnosis, suggesting room for improvement in asthma management practices. Underdiagnosis, coupled with poor symptom control among diagnosed asthmatic subjects, has prompted school districts in the United States and elsewhere to implement asthma-screening programs to detect children with undiagnosed or suboptimally managed asthma.[11,20-23]

Feasibility issues for school-based screening programs include staffing needed to achieve high response rates and high false-positive rates requiring either a second-stage screen or clinician review. Our protocol involved telephone follow-up among 36% of students to achieve the high response rates. This would be difficult for a school system with limited available staff. Other schools have reported high response rates with asthma screening as part of enrollment or as part of a mandatory annual school nurse health survey.[11,22] School-based screening programs most typically use a questionnaire as the first stage in screening. In general, school-based questionnaire screening has been found to have a high sensitivity and reasonable specificity. However, because of low positive predictive values and somewhat low specificity, a second stage of screening is necessary.[22]

In summary, by using similar questionnaire items, the prevalence of asthma in these 2 rural Iowa counties was comparable with that found in inner-city elementary schools in Minneapolis, Chicago, and Seattle and higher than that observed in rural Canada and Europe. This casts doubt on the theory that rural life is protective for asthma in the United States. Although the study counties were similar in agricultural production, unmeasured risk factors might account for the apparent protective effect of farming observed in Keokuk County but not in Louisa County and might also explain differing findings among published studies. Prevalence of wheeze was lower among those who lived on farms in one county but not another. Among those with current wheeze, the probability of being given a diagnosis of asthma and of having severe symptoms was equivalent for farm and nonfarm residents, suggesting that triggers of asthma exacerbations, as well as health care access issues, are ubiquitous in farming communities.

To appropriately treat asthma, diagnosis is important. Less than half of children with frequent symptoms and three fourths with severe symptoms reported ever being given a diagnosis of asthma. These findings and those of others suggest that underdiagnosis of asthma is common. When coupled with the high rate of frequent or severe symptoms among those given a diagnosis of asthma (43.0% and 24.6%, respectively), the public health importance of effective rural models for asthma diagnosis and management is evident.

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REFERENCES

1. Asher MI, Weiland SK, on behalf of the ISAAC Steering Committee. The International Study of Asthma and Allergies in Childhood (ISAAC). Clin Exp Allergy 1998;28(suppl 5):52-66.
2. The International study of Asthma and Allergies in Childhood (ISAAC) Steering Committee. Worldwide variations in the prevalence of asthma symptoms: the International Study of Asthma and Allergies in Childhood (ISAAC). Eur Respir J 1998;12:315-35.
3. Braun-Fahrlander C, Gassner M, Grize L, et al. Prevalence of hay fever and allergic sensitization in farmer's children and their peers living in the same rural community-SCARPOL Team. Swiss Study on Childhood Allergy and Respiratory Symptoms with Respect to Air Pollution. Clin Exp Allergy 1999;29:28-34.
4. Ernst P, Cormier Y. Relative scarcity of asthma and atopy among rural adolescents raised on a farm. Am J Respir Crit Care Med 2000;161:1563-6.
5. American Thoracic Society. Respiratory health hazards in agriculture. Am J Respir Crit Care Med 1998;158:S1-76.
6. Kogevinas M, Anto JM, Sunyer J, Tobias A, Kromhout H, Burney P. Occupational asthma in Europe and other industrialized areas: a population-based study. European Community Respiratory health Survey Study Group. Lancet 1999;353:1750-4.
7. Douwes J, Thorne PS, Pearce N, Heederik D. Biological agents—recognition. In: Perkins J, editor. Modern industrial hygiene. Vol 4. Cincinnati (OH): American Conference of Governmental Industrial Hygienists; 2002.
8. Yawn BP, Mainous AG, Love MM, Hueston W. Do rural and urban children have comparable asthma care utilization? J Rural Health 2001;17:32-9.
9. Tong S, Drake P. Hospital admission and mortality differentials of asthma between urban and rural populations in New South Wales. Aust J Rural Health 1999;7:18-22.
10. Williams JK, McCarthy AM. School nurses' experiences with children with chronic conditions. J School Health 1995;65:234-6.
11. Bauer EJ, Lurie N, Grant EN. Screening for asthma in an inner-city elementary school in Minneapolis, Minnesota. J Sch Health 1999;69:12-6.
12. Rosier MJ, Bishop J, Nolan T, Robertson CF, Carlin JB, Phelan PD. Measurement of functional severity of asthma in children. Am J Respir Crit Care Med 1993;149:1434-41.
13. 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;358:1129-33.
14. Riedler J, Eder W, Oberfeld G, Schreuer M. Austrian children living on a farm have less hay fever, asthma and allergic sensitization. Clin Exp Allergy 2000;30:194-200.
15. Downs SH, Marks GB, Mitakakis JD, et al. Having lived on a farm and protection against allergic diseases in Australia. Clin Exp Allergy 2001;31:570-5.
16. Wickens K, Lane JM, Fitzharris P, et al. Farm residence and exposures and the risk of allergic diseases in New Zealand children. Allergy 2002;57:1171-9.
17. Merchant JA, Stromquist AM, Kelly KM, et al. Chronic disease and injury in an agricultural county: The Keokuk County Rural Health Cohort Study. J Rural Health 2002;18:521-35.
18. Siersted HC, Boldsen J, Hansen HS, et al. Population-based study for underdiagnosis of asthma in adolescence. Odense schoolchildren study. BMJ 1998;316:613-5.
19. Kolnnr B, Beissel E, van den Bosch WJ, et al. Asthma in adolescents and young adults: screening outcome versus diagnosis in general practice. Fam Pract 1994;11:133-40.
20. Frank TL, Frank PI, McNamee R, et al. Assessment of a simple scoring system applied to a screening questionnaire for asthma in children aged 5-15 yrs. Eur Respir J 1999;14:1190-7.
21. Frank PI, Frank TL, Cropper J, et al. The use of a screening questionnaire to identify children with likely asthma. Br J Gen Pract 2001;51:117-20.
22. Glasgow NJ, Ponsonby AL, Yates RE, McDonald T, Attewell R. Asthma screening as part of a routine school health assessment in the Australian Capital Territory. Med J Australia 2001;174:384-8.
23. Freeman NCG, Schneider D, McGarvey P. School-based screening for asthma in third-grade urban children: the Passaic asthma reduction effort survey. Am J Public Health 2002;92:45-6.