School Proximity to Concentrated Animal Feeding Operations and Prevalence of Asthma in Students*

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Study objectives: **Asthma prevalence and severity are rising in industrialized nations. Studies supporting the hygiene hypothesis suggest that being raised on a farm protects against atopy and, often, asthma. In rural United States, however, an increased rate of asthma has been found among schoolchildren. We hypothesized that the rural US environment may not be protective against airway inflammation, perhaps due to environmental effluents from a relatively high number of concentrated animal feeding operations (CAFOs). We compared the prevalence of asthma in two Iowa elementary schools, one adjacent to a CAFO, and the other distant from any large-scale farming operations.**

Design: **Cross-sectional questionnaire-based study.**

Setting: **Two rural Iowa elementary schools: the study school is located one-half mile from a CAFO, and the control school is distant from any large-scale agricultural operation.**

Participants: **Children, kindergarten through grade 5, who attended either the study school or the control school.**

Results: **Children in the study school had a significantly increased prevalence of physician-diagnosed asthma (adjusted odds ratio, 5.71; p = 0.004). Although this group was more likely to live on a farm and have parents who smoke, these potentially confounding variables did not account for increased prevalence in a multivariate model. No difference in measures of asthma severity was found between the two populations. Because different sets of physicians are responsible for the medical care of the groups of children, it is possible that physician bias is responsible for the different prevalence of asthma diagnoses. This was not explored in the study.**

Conclusions: **This study supports a role for exposure to rural environmental toxicants in the etiology of asthma, and suggests a need for further study of this relationship.**

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Key words: environmental air pollutants; pediatrics; rural health

Abbreviations: CAFO = concentrated animal feeding operation; ED = emergency department; OR = odds ratio

Asthma results from complex interactions between genetic predisposition and environmental influences.[1] Its prevalence has increased in industrialized nations over the past several decades despite improved medical care and living conditions.[2] Although environmental pollution has been linked to asthma exacerbations, asthma prevalence does not correlate well with measures of air quality. Other proposed etiologic factors include environmental tobacco smoke, airtight buildings, declines in breast feeding,

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increased obesity, and reduced fitness[3–7]; none of these hypotheses completely explains the current trends in asthma prevalence. An important alternative theory, the hygiene hypothesis, postulates that increasing asthma and atopy may result from decreased childhood exposure to infections and microbial products. These exposures promote immune responses that can down-regulate the T-helper type 2 immune pattern associated with asthma and atopy.[8] Since exposure to microbial products appears to offer some protection against asthma and atopy, it is reasonable that childhood exposure to a microbe-laden agricultural environment may offer similar benefit. Indeed, numerous studies have shown that children raised in a farm environment,[9–13] as well as farmers who enter agriculture as adults,[14] are relatively protected from asthma and atopy. In the United States, however, this protective effect of an agricultural environment has not been observed; indeed, in some cases, the opposite seems to be the case. A study[15] of a rural community in Iowa found a significantly higher rate of childhood asthma than the national average.

There are a number of characteristics of farms in the United States, and in Iowa in particular, that distinguish them from those in Europe and elsewhere. Iowa is one of the largest hog producers in the world, and most hogs are reared in large-scale "factory farms" or concentrated animal feeding operations (CAFOs) that house large numbers of animals (> 3,500) in high density. Operations of this type release multiple irritant and inflammatory substances that can adversely affect the health of workers as well as the air quality in surrounding communities.[16–18] This raises the possibility of a causal relationship between CAFOs and increased rates of asthma among children in rural environments. To evaluate the hypothesis that childhood exposure to effluents from CAFOs may promote airways disease and symptoms, we surveyed students from two elementary schools in rural Iowa, one located in proximity to a CAFO, and the other distant from any large-scale animal farming operation, regarding their prevalence of asthma and airway symptoms.

Materials and Methods

Study Design

This cross sectional study was designed to assess whether location of an elementary school in the vicinity of a CAFO is associated with higher rates of asthma. The study was reviewed and approved by the Institutional Review Board of the University of Iowa, as well as by officials of both school districts participating in the study. Parents of all participants, who included students in kindergarten through fifth grade in participating schools, were contacted by mail and asked to fill out a questionnaire. Nonresponders were telephoned up to three times to request participation. Data collection was performed between February and June 2003.

Study Location

Two schools in rural areas of Iowa were selected. The study school is located in Northeast Iowa approximately one-half mile from a CAFO that houses approximately 3,800 hogs. The control school is located in East Central Iowa, > 10 miles away from any CAFO.

Questionnaire

The questionnaire had 20 items (available as on-line Appendix). Two questions involved the location of the primary residence (rural vs town) and whether the participant is currently living on a farm. Eight items were adapted from the International Study on Asthma and Allergies in Children[19] and relate to frequency of asthma symptoms, nighttime and exercise symptoms, and medication use. The remainder covered asthma-related issues such as activity limitation, urgent-care utilization, and frequency of rescue inhaler use. A similar questionnaire has been used and validated in a study[15] on rural school children in Iowa.

Diagnosis of Asthma

Three items on the questionnaire were used to determine whether the child had asthma: item 3 ("Has a doctor ever told you that your child has asthma?"); item 5 ("Has your child had wheezing or whistling in the chest in the last 12 months?"); or item 7 ("Has your child used medication for his or her wheezing in the last 12 months?").

Statistics and Data Analysis

This was a cross-sectional study assessing the prevalence of asthma diagnosis, symptoms, and risk factors. The χ^2 test was used to evaluate differences between variables with a dichotomous outcome. For continuous variables, we utilized a *t* test. A multivariate logistic regression model was fitted to analyze possible interactions between variables and the association between the outcome (asthma) and other variables. The dependent variable in the multivariate regression model was physician-diagnosed asthma. Variables, other than the primary outcome of interest, were included in the model if they were considered to have a plausible causal relationship with asthma (*eg*, tobacco smoke exposure, farm rural residence, and pet ownership). Significance levels were set at $p < 0.05$. Statistical analysis was accomplished using statistical software (version 8; SAS Institute; Cary, NC).

Results

Study Population

The study school serves 116 students in kindergarten through grade 5; the control school serves 456 students in kindergarten through grade 5. Mean age is higher in the study school: 9.5 years vs 8.7 years. Children in the study school were more likely to live in a rural area and on a farm, have smoking parents, and have a pet cat. Gender distribution was similar between the two schools. Individual family income levels were not assessed in this study, but mean yearly income is very similar in both locations according to US Census Bureau 2004 data[20]; racial and ethnic makeup differs slightly: the population in the area of the study school is 97% white, while the population in the area of the control school is 90% white. Study population characteristics are outlined in Table 1. Response rates were similar in the two schools: 61 participants (52.6%) responded from the study school, and 248 participants (54.4%) responded from the control school. Nine participants (7.8%) from the study school and 32 participants (7.0%) from the control school requested not to be included in the study.

Prevalence of Asthma

A significant difference in the prevalence of physician-diagnosed asthma was found between the two schools: 12 children (19.7%) from the study school and 18 children (7.3%) from the control school gave a history of physician-diagnosed asthma (odds ratio [OR], 5.60; p = 0.0085). Although the diagnosis of asthma was more common among students in the study school, medication use and emergency department (ED) visits did not significantly differ between the two groups (Table 2). Eighteen percent of children from the study school but only 9.7% of children from the control school reported wheezing in the past year, which nearly reached statistical significance (p = 0.07). Using the broadest definition of asthma (physician diagnosis, asthma-like symptoms, or asthma medication use), the prevalence of asthma in the study school remained significantly greater than that in the control school (study school, 24.6%; control school, 11.7%; p = 0.0412). When analyzed in a multivariate model that included smoking status, pet ownership, age, and residence in a rural area or on a farm, the positive association between the study school and physician-diagnosed asthma remained (adjusted OR, 5.719; p = 0.0035) [Table 3]. Using multivariate analysis, the secondary outcomes of asthma severity and alternative asthma definitions did not show increased levels of statistical significance.

Table 1—*Characteristics of Study and Control Populations**

Variables	Study School	Control School	p Value
Response rate	61 (52.6)	248 (54.4)	NS
Refused to participate	9 (7.8)	32 (7.0)	NS
Mean age, yr	9.5	8.7	0.05
Male gender	32 (52.5)	134 (54.0)	NS
Live in rural area, %	90.4	73.4	< 0.05
Living on a farm, %	63.5	6.8	< 0.0001
Parents smoking, %	28.9	14.9	< 0.05
Cat in the home, %	63.5	39.4	< 0.005
Dog in the home, %	71.2	57.2	NS

*Data are presented as No. (%) unless otherwise indicated. NS = not significant.

Table 2—*Prevalence of Asthma Diagnosis, Symptoms, and Exacerbations**

Variables	Study School (n = 61)	Control School (n = 248)	p Value, Univariate Analysis
Physician diagnosis of asthma	12 (19.7)	18 (7.3)	< 0.01
Whistling or wheezing (ever)	17 (27.9)	53 (21.4)	NS
Whistling or wheezing (past year)	11 (18.0)	24 (9.7)	0.07
Active inhaler medication use	8 (13.1)	22 (8.9)	NS
Asthma (by any of three criteria)†	15 (24.6)	29 (11.7)	< 0.05
ED visits in past year	2 (3.27)	7 (2.8)	NS

*Data are presented as No. (%). See Table 1 for expansion of abbreviation.

†Physician diagnosis, wheezing in past year, or active inhaler medication use.

Asthma and Household Variables

A univariate analysis showed a significant association between currently smoking parents and a diagnosis of asthma (p = 0.0486; Table 4). This association disappeared in the multivariate model (Table 3). Smoking was significantly less common in the rural population (rural, 14%; vs nonrural, 30%; p = 0.0044). No association was found between asthma and pet (cat or dog) ownership. Living in a rural area or on a farm did not alter the risk of asthma in this study (Table 4). A subgroup analysis of all the asthmatics (n = 30) showed no difference in parental smoking rates between asthmatics from the two schools, but parental smoking rates were significantly higher in asthmatics compared with nonasthmatic children (33.3% vs 16.1%) [Table 4].

Severity of Asthma Was Not Different in the Two Populations

When comparing the two populations of subjects with physician-diagnosed asthma, no difference was

Table 3—*Multivariate Model of Factors Potentially Associated With Asthma Prevalence*

Variables	OR	95% Confidence Interval	p Value
School*	5.72	1.776–18.422	0.0035
Living in rural area	0.67	0.223–2.035	0.4832
Living on a farm	3.99	0.905–17.597	0.0676
Parents smoking	1.77	0.602–5.205	0.2997
Cat in the home	0.84	0.546–1.291	0.4261
Dog in the home	0.88	0.556–1.405	0.6011

*OR for control school as reference point.

Table 4—*Relationship Between Physician-Diagnosed Asthma and Household Variables**

Variables	Asthma (n = 30)	No Asthma (n = 279)	p Value, Univariate Analysis
Parents smoking	10 (33.3)	45 (16.1)	0.049
Rural residence	22 (73.3)	215 (77.1)	NS
Living on a farm	5 (16.7)	51 (18.3)	NS
Cat in the home	12 (40)	124 (44.4)	NS
Dog in the home	16 (60.0)	169 (60.1)	NS

*Data are presented as No. (%). See Table 1 for expansion of abbreviation.

seen in severity of symptoms as measured by frequency of asthma attacks, asthma-related sleep disturbance, visits to the ED, limitations on activity, and the use of rescue inhalers (Table 5).

Discussion

A significant difference was found in the prevalence of physician-diagnosed asthma among students in the two schools studied. In the study school, located near a CAFO, the asthma prevalence was quite high, 19.7%, approaching the prevalence of asthma reported among inner-city socioeconomically disadvantaged children.[21] The prevalence in the control school was 7.3%, which is quite close to the overall rate reported for Iowa of 6.7%.[22] The presence of asthma was significantly related to parental smoking in a univariate analysis, which is not surprising because environmental tobacco smoke is known as a risk factor for asthma in children and adults.[23–25] Smoking was more common among parents in the study population, but the significance of parental smoking disappeared in a multivariate model taking into account pet ownership, age, and residence in a rural area or on a farm; in this analysis, smoking did not affect the positive association between physician-diagnosed asthma and the study population. Limitation of activity and disturbed sleep due to asthma symptoms were quite common in asthmatic children from both schools, possibly suggesting inadequate asthma control, but there was no significant difference in markers of severity between the groups. There was no connection between pet ownership and asthma, in contrast to other studies[26] that have found early-life pet exposure protective. Living in a rural area was neither a risk factor nor protective in our study in contrast to previous studies[9,13] showing a potential benefit. Living on a farm approached statistical significance as a risk factor for asthma (OR, 3.99; p = 0.068). As the majority of the children in the study population lived on a farm, this cannot be excluded as a significant factor.

Table 5—*Severity of Symptoms**

Variables	Study School (n = 12)	Control School (n = 18)	p Value
Limitations on activity	5 (41.7)	8 (44.4)	NS
Four or more asthma attacks in past year	2 (16.7)	4 (22.2)	NS
Sleep disturbed by asthma	4 (33.3)	5 (27.8)	NS
Visits to an ED in past 12 mo	1 (8.3)	2 (11.1)	NS
Rescue inhaler use three or more times a month	7 (58.3)	7 (38.9)	NS
One or more of above items	8 (66.7)	10 (55.6)	NS

*Data are presented as No. (%). See Table 1 for expansion of abbreviation.

Our study has several limitations. First is the relatively low response rate: only slightly over half of eligible participants participated in the study, leading to a potential for selection bias. However, the response rates were similar in both populations, thus likely minimizing the effect of such a bias on study results. Second, our definition of asthma includes reporting of physician-diagnosed asthma, raising a potential for recall bias. Participants were not informed of our hypothesis, however, and were not aware whether they were in the study or comparison group, making this less likely. Furthermore, since different physicians provide medical care for children who attend the two schools, one of the groups may have been more or less likely to receive a diagnosis of asthma for similar symptoms. Addressing the diagnostic criteria for asthma among the physicians in these communities was outside the scope of this study, but would be an important aspect of future studies; we have previously shown[27] that understanding of the National Heart, Lung, and Blood Institute guidelines and diagnostic criteria can vary widely, even among asthma specialists. Third, smoking rates were different among parents in the two populations compared. However, although smoking prevalence in general is higher among parents of the study students, using a multivariate model that included parental smoking did not decrease the significantly different asthma prevalence rates in the study and the control school. Finally, it is possible that the socioeconomic background of children differ between the two schools. The study population is predominantly rural with a large farming community, while the control population is more diverse. The US Census Bureau shows similar income levels on a community basis, but we have no data on the household incomes for participants in this study.

Environmental pollution from CAFOs consists of a mixture of organic dust and chemicals including

NH_3 and H_2S. Swine dust, endotoxin, and endotoxin-laden grain dust with and without ammonia have been shown to be a respiratory irritant in numerous exposure studies.[28–31] Furthermore epidemiologic studies[32] have shown that exposure to swine dust causes decline in pulmonary function over time. Although exposure to allergens, endotoxin, and other bioproducts may potentially have a beneficial effect on the developing immune system, protecting from the development of asthma and allergies, exposure to the complex mixture of airborne pollutants emanating from CAFOs, sometimes in high concentrations,[16] may have a detrimental effect.

The difference in asthma prevalence that we found in this cross-sectional study of two schools may be linked to multiple factors, including socioeconomics, different medical practices, and household smoking patterns. Although each of these factors could play a role, it is impossible to exclude a role for environmental factors, such as the proximity of the school to CAFOs and exposures generated by family farms, on the profound difference in asthma rates. Our findings are similar to those of Chrischilles et al,[15] who found a significantly increased asthma prevalence in a rural population of Iowa children. The hypothesis that CAFOs contribute to environmental pollution adversely affecting respiratory health in young children needs to be further explored. A prospective study in which concentrations of environmental pollutants are correlated with airway symptoms and physiologic measures in exposed children will be important to follow up these findings.

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