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ORIGINAL ARTICLE

Asthma Among Rural Minnesota Adolescents

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This study examined the prevalence of and risk factors for wheezing and asthma in rural Minnesota adolescents. A survey querying about wheezing, asthma, farm residence, and other respiratory-related factors was administered to all 9th to 11th grade students ($N = 13,490$) in a stratified, random sample of high schools in rural Minnesota. Nearly one in 8 (12.6%) students reported ever-diagnosed asthma, and 9.2% reported current asthma. Students living on farms reported less wheezing and asthma than rural non-farm students. Obesity and smoking were associated with wheezing and asthma in all rural adolescents. Asthma rates increased with age among girls and may be largely accounted for by simultaneous increases in smoking rates. Despite the apparent protective effect of farm residence, asthma remains a significant public health issue among rural Minnesota adolescents.

Keywords asthma, wheezing, adolescent, rural, farm

INTRODUCTION

The prevalence of asthma has increased among children in the U.S. over the past two decades (1). However, the prevalence of asthma among rural adolescents is only beginning to be characterized, particularly the association of asthma with living on a farm versus rural non-farm residence (2–4). The farming population is of particular interest because the hygiene hypothesis suggests that living on a farm as a child may confer a protective effect against the later development of allergies and asthma (5, 6). It is unclear whether this effect varies by type of farming. Paradoxically, for those children who do go on to develop allergies and asthma, the farming environment has many potential allergens and asthma triggers, such as pollen, grain dust, animal dander, and cold air during the winter (7, 8).

The objectives of this study were to use a school-based survey to estimate the prevalence of wheezing and asthma among rural Minnesota adolescents and to evaluate potential risk factors including farm residence and farm work. This information could be useful in determining allocation of future resources for statewide school-based asthma programs.

METHODS

Data in this study were collected as part of a longitudinal study of work, injuries, and illness among adolescents enrolled in rural Minnesota high schools. Eligible for inclusion were 190 public high schools with at least 20 students in each grade and located in one of 67 Minnesota counties designated as rural according to U.S. Department of Agriculture criteria. Schools from three rural counties were excluded owing to their participation in a previous study. To achieve a more representative sample of schools and potential agricultural experiences, two additional stratification factors were used in school selection: school size (three categories) and the predominant types of agriculture at the county level (four regions). Schools within each agricultural region and size category were recruited on a random basis. The goal was to recruit four small schools, four medium schools, and two large schools from each of the four agricultural regions (plus an additional medium school from a more sparsely populated region). By the start of the study, 41 (65%) of 63 recruited schools agreed to participate, representing a population of 15,368 students in grades 9 through 11.

Participation of schools and students was completely voluntary, and passive consent was obtained through letters to students' families. The study protocol was approved by the Minnesota Department of Health Institutional Review Board. All principals completed online Human Subject Assurance training from the U.S. Office of Human Research Protection and Federalwide Assurance of Protection for Human Subjects documentation as required by the U.S. Department of Health and Human Services.

Students were surveyed a total of four times over a 2-year period. For this analysis, only data from the initial survey, administered in the fall 2001 and describing events from June–August 2001, are presented. All students in grades 9 to 11 in each school were asked to complete a machine-readable survey that included 10 questions about asthma. Questions about demographics, farm residence, height, weight, jobs held, and smoking status were also included. Farm residence was defined as a yes answer to ''Do you live on a farm or ranch that is actively involved in agricultural production?'' A farm was defined as any place producing or selling $1,000 or more of agricultural products. Those who reported living on a farm were then

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asked to indicate the type of farming or ranching done, specifically beef cattle, hogs, row crops, dairy, small grains, turkey/poultry, or other. Farm work done by the student was defined as paid or unpaid work, including chores, done on a farm under the supervision/employment of a farmer or work done as a service to the farmer, but under the supervision of an agri-business provider.

Completed surveys were scanned and results were entered into a database. Data were then edited for consistency of responses, out-of-range responses, skip patterns, and missing data.

Four questions were used to determine the asthma status of each student: 1) Have you had wheezing or whistling in your chest in the past 12 months? 2) Have you had wheezing or whistling in your chest in the past 12 months when you exercise? 3) Has a doctor ever told you that you have asthma? and 4) If yes, do you still have asthma?

Students were assigned to one or more outcome categories based on their responses to these questions. *Ever-diagnosed asthma* was defined as reporting a doctor's diagnosis of asthma. *Current asthma* was defined as reporting a doctor's diagnosis and still having asthma (with or without reported wheezing). *Potential asthma* was defined by current wheezing, but no doctor's diagnosis of asthma. A separate category, *potential exercise-induced asthma*, was created for those who reported wheezing only during exercise.

Body mass index (BMI) was calculated using self-reported height and weight. Overweight was defined as a BMI greater than or equal to the 85th percentile as defined by the Centers for Disease Control and Prevention (CDC) for sex and age (9). We excluded as an outlier any BMI that was less than 11 or greater than 36.

Simple descriptive statistics were used to describe the population. Prevalence estimates were weighted to account for the stratified-cluster sampling methodology. Logistic regression was used to test for trends in asthma prevalence by age and sex. Adjusted odds ratios and 95% confidence intervals were calculated using multivariate logistic regression to measure the effect of various factors on current wheeze, exercise wheeze, ever-diagnosed asthma, and current asthma. Chi-square tests were used to test for significant differences in prevalence between farm types. Analyses were conducted using SAS statistical software (SAS/Stat, Version 8.02, SAS Institute Inc, Cary, NC).

RESULTS

The overall response rate was 89.1%, with a total of 13,490 eligible surveys included in this analysis. Table 1 shows the demographics of the students. Ages ranged from 13 to 21 years, with the majority (99.5%) of the students 14 to 17 years of age.

TABLE 1.—Demographics of the study population (N = 13,490).

	Percent
Sex	
Girls	49.0
Boys	51.0
Grade	
9	33.2
10	33.5
11	33.2
Race/ethnicity	
White	93.0
Farm residence	
Yes	13.7
Farm type	
Includes livestock	70.9
Crop-only	29.1
Worked in previous 3 months	19.3
Region	
Dairy/poultry	24.6
Swine/corn/soybeans	28.5
Forestry/wild rice	30.6
Grain	16.3
Body mass index[a] $\geq$ 85th percentile[b]	
Girls	17.8
Boys	31.4
Current smoker	
Overall	12.6
Girls	13.7
Boys	11.6
Exposed to smoke at home	
Sometimes or often	33.7

[a]Body mass index = weight (kg)/height (m)^2.
[b]CDC percentiles for sex and age.

Overall Prevalence Estimates

Table 2 shows the overall prevalence estimates for this population. For all ages combined, the prevalence of ever-diagnosed asthma was 12.6% (95% CI = 11.8, 13.4), while the prevalence of current asthma was 9.2% (95% CI = 8.7, 9.8). The prevalence of wheezing in the past 12 months was 17.5% (95% CI = 16.7, 18.3), and the prevalence of wheezing during exercise in the past 12 months was 21.2% (95% CI = 20.2, 22.2).

Girls were more likely than boys to report wheezing in the past 12 months and wheezing during exercise. However, girls and boys were just as likely to report ever having a doctor's diagnosis of asthma. Girls were more likely than boys to report currently having asthma, although the difference was not statistically significant. There was a significantly greater percentage of girls than boys in both the potential asthma and potential exercise-induced asthma categories.

Asthma Status by Age, Sex and BMI

Asthma rates and trends differed for boys and girls. Rates of current asthma were higher for boys than girls at age 14, after which rates were higher for girls. The percentage of girls with current asthma increased with age (8.7%, 9.5%, 10.7%, and 11.2% for ages 14, 15, 16, and 17, respectively), while the percentage of boys with current asthma decreased with age (9.8%, 7.3%, 8.4%, and 5.8% for ages 14, 15, 16, and 17). The increase in current asthma prevalence by age among girls was statistically significant (p value for trend = 0.02), as was the decrease among boys (p value for trend = 0.01). When we stratified these rates by current smoking status, which increased with age for both sexes in this population, we found evidence of an increase in the prevalence of asthma by age among female smokers, but the trend was not significant (see Figure 1).

TABLE 2.—Prevalence[a] of asthma in rural Minnesota adolescents, by sex.

	Overall		Girls (n = 6,567)		Boys (n = 6,831)	
	%	(95% CI)	%	(95% CI)	%	(95% CI)
Wheeze in past 12 months	17.5	(16.7, 18.3)	19.7	(18.5, 20.9)	15.4	(14.2, 16.5)
Wheeze during exercise past 12 months	21.2	(20.2, 22.2)	25.2	(23.9, 26.6)	17.3	(16.0, 18.7)
Ever diagnosed with asthma	12.6	(11.8, 13.4)	13.0	(11.8, 14.1)	12.2	(11.0, 13.3)
Current asthma	9.2	(8.7, 9.8)	10.1	(9.1, 11.0)	8.5	(7.7, 9.2)
Potential	7.9	(7.2, 8.5)	8.9	(8.0, 9.7)	7.0	(6.3, 7.7)
Potential exercise-induced asthma only	5.1	(4.7, 5.6)	6.4	(5.8, 7.0)	4.0	(3.4, 4.6)

CI = Confidence interval.

[a]Weighted to account for stratified-cluster sampling design.

We found no evidence of an increase among nonsmoking girls. Among boys, the prevalence of asthma decreased by age in both smokers and nonsmokers, with a statistically significant decrease observed only in nonsmokers (p = 0.01). The difference in asthma prevalence between smoking and nonsmoking girls (13.1% vs. 9.7%) was greater than the difference in prevalence between smoking and nonsmoking boys (9.5% vs. 8.4%).

Table 3 shows adjusted odds ratios for the associations between various risk factors and asthma or wheezing status. Overweight students (BMI $\geq$ 85th percentile) were more likely than students who were not overweight to report wheezing (OR = 1.18; 95% CI = 1.05, 1.32), wheezing during exercise (OR = 1.28; 95% CI = 1.15, 1.42), ever-diagnosed asthma (OR = 1.31; 95% CI = 1.15, 1.49), and current asthma (OR = 1.29; 95% CI = 1.12, 1.49).

Smoking Exposure

Students who reported that they currently smoked were more likely to report wheezing (OR = 1.83; 95% CI = 1.60, 2.10), wheezing during exercise (OR = 1.86; 95% CI = 1.63, 2.12), ever-diagnosed asthma (OR = 1.20; 95% CI = 1.01, 1.42), and current asthma (OR = 1.20; 95% CI = 1.01, 1.44). Students who reported that someone in their home smoked around them were more likely to report wheezing (OR = 1.29; 95% CI = 1.16, 1.43) and wheezing during exercise (OR = 1.22; 95% CI = 1.11, 1.35). However, these students were no more likely than those without household smoking to report ever-diagnosed asthma (OR = 1.07; 95% CI = 0.94, 1.21) and current asthma (OR = 1.07; 95% CI = 0.94, 1.22).

Farms and Asthma Status

Students living on a farm were less likely than those not living on a farm to report wheezing in the past 12 months (OR = 0.84; 95% CI = 0.72, 0.98) or wheezing during exercise (OR = 0.82; 95% CI = 0.71, 0.95). They were also less likely to report ever having an asthma diagnosis (OR = 0.78; 95% CI = 0.65, 0.94) and less likely to report current asthma (OR = 0.77; 95% CI = 0.63, 0.93).

Among those students who reported living on farms (n = 1,790), 70.9% reported that the type of farming or ranching done on their farm included livestock (e.g., beef cattle, hogs, dairy). The rest of the farms (29.1%) were crop-only (e.g., corn, soybeans, sugar beets). We found no difference in the prevalence of ever-diagnosed asthma

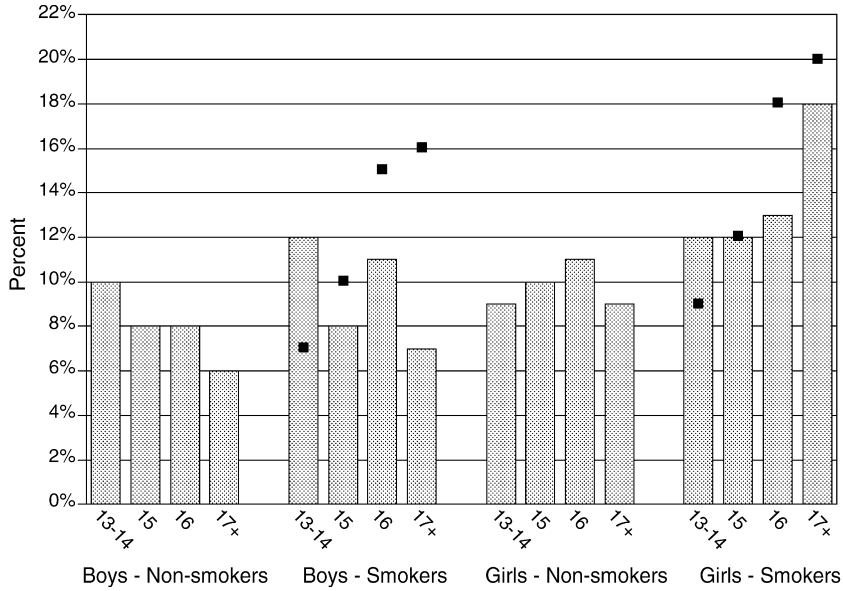

FIGURE 1.—Percentage of students with current asthma by age, sex, and smoking status (black squares are smoking rates).

TABLE 3.—Adjusted[a] odds ratios for the association for asthma outcomes.

	Wheezing		Wheeze during exercise		Ever-diagnosed asthma		Current asthma	
	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Age (>15 vs. ≤ 15)	0.96	(0.86, 1.06)	0.84	(0.76, 0.92)	1.05	(0.93, 1.17)	1.03	(0.91, 1.17)
Sex (boys vs. girls)	0.71	(0.64, 0.79)	0.59	(0.54, 0.65)	0.89	(0.79, 1.00)	0.79	(0.70, 0.90)
Current smoking (yes vs. no)	1.83	(1.60, 2.10)	1.86	(1.63, 2.12)	1.20	(1.01, 1.42)	1.20	(1.01, 1.44)
Household smoke (yes vs. no)	1.29	(1.16, 1.43)	1.22	(1.11, 1.35)	1.07	(0.94, 1.21)	1.07	(0.94, 1.22)
BMI ≥ 85th percentile (yes vs. no)	1.18	(1.05, 1.32)	1.28	(1.15, 1.42)	1.31	(1.15, 1.49)	1.29	(1.12, 1.49)
Farm residence (Yes vs. No)	0.83	(0.71, 0.97)	0.82	(0.71, 0.95)	0.78	(0.65, 0.94)	0.77	(0.63, 0.94)

OR = odds ratio; CI = confidence interval.
[a]Adjusted for variables in the table and agricultural region.

(10.5% vs. 9.9%, $p = 0.72$), current asthma (7.7% vs. 7.1%, $p = 0.65$), wheezing (15.5% vs. 13.8%, $p = 0.37$), or exercise wheezing (17.6% vs. 17.7%, $p = 0.97$) between students who lived on farms with livestock versus those who lived on crop-only farms.

Nearly 20% of the students reported that they had worked on a farm (including chores) during the previous 3 months (June through August). This percentage varied by agricultural region, with the lowest in the forest/wild rice region (11.5%) and the highest in the grain region (32.2%). Of those who reported living on a farm, 64.4% reported doing farm work, while 8% of the non-farm residents did farm work.

Among those students who worked and did not live on a farm ($n = 9{,}068$), we found that those who reported working on a farm were just as likely as those whose jobs did not include farm work to report ever-diagnosed asthma, current asthma, wheezing, or exercise wheezing. However, we did find that boys who did farm work reported more wheezing than boys not doing farm work (18.2% vs. 15.1%; $p = 0.05$).

DISCUSSION

This study provides the first representative estimates of the prevalence of wheezing and asthma among rural Minnesota adolescents. The prevalence of ever-diagnosed asthma in this population (12.6%) is lower than the latest estimate from the Youth Risk Behavior Surveillance System, which found that 18.9% of high school students nationwide reported ever-diagnosed asthma (S. Merkle, CDC, personal communication). It is similar to, although slightly lower than, that found in rural Iowa (13.4%) for children ages 6–14 (3). A recent survey of 11- to 16-year-old children in a largely rural area of Texas found a 20.0% prevalence of ever-diagnosed asthma (10). In a survey of 122,829 adolescents 12 to 14 years of age enrolled in North Carolina public schools in 1999 to 2000, the prevalence of ever-diagnosed asthma was 15.8%, whereas the prevalence of current asthma was 9.9%, with rates slightly lower in urban than rural areas (11, 12). A 2003 survey of 7th and 8th graders from a convenience sample of 15 Minnesota schools outside of the Minneapolis-St. Paul metropolitan area identified 13.5% with a history of doctor-diagnosed asthma and 8.4% with current asthma (13).

Because the potential asthma category (students reporting any wheezing in the past 12 months, but without a doctor's diagnosis of asthma) presumably includes substantial numbers of undiagnosed asthmatics, the 9.2% current asthma figure likely underestimates the true impact of asthma in this population. Because wheezing is not always indicative of asthma (14), and because our survey did not ask about other asthma symptoms (e.g., nighttime cough), the exact prevalence of undiagnosed asthma in this population cannot be determined. However, we can assume that the overall percentage of students currently affected by asthma is between 9% and 17%.

In our study, a higher percentage of students reported wheezing during exercise in the past year than reported any wheezing in the past year. This apparent contradiction may be due to the order in which the questions were asked. Some students answered no to wheezing, but when asked about wheezing during exercise in the next question, may have realized that they had wheezed in that situation and answered yes. The International Survey of Allergies and Asthma in Children (ISAAC) study, a worldwide survey of the prevalence of asthma using a standardized questionnaire, has observed the same pattern, with 13- and 14-year olds in most countries more likely to report wheezing during exercise in the past year than any wheezing in the past year (15).

We found that the prevalence of asthma among girls increased with age, consistent with an increase in the incidence of asthma by age among girls observed in a longitudinal population-based study of schoolchildren in Rochester, Minnesota (16). However, once we took smoking status into account, we found only a slight increase in asthma by age among female smokers that was not statistically significant, and no apparent increase with age among nonsmoking girls. The prevalence of current asthma was higher among female smokers than nonsmokers at all ages; the same pattern was seen to a lesser degree among boys. This finding supports the theory that, along with hormones, the increase in asthma among

adolescent girls may be due in large part to increasing smoking rates (17).

We found an association between household smoking and wheezing but not asthma, despite the fact that exposure to secondhand smoke is known to increase the risk of asthma in children. Our findings could be due to a diagnostic bias in this population; parents who smoke may be less likely to recognize wheezing in their children as a possible symptom of asthma and thus, less likely to take them to a doctor for evaluation. Data from the Behavioral Risk Factor Surveillance System (18) and the Minnesota 2003 Adult Tobacco Survey (Minnesota Department of Health, unpublished data, 2003) indicate that adults who smoke are more likely to be of lower socioeconomic status than those who do not; thus, it could also be that these parents may be more likely to have financial, transportation, or other barriers to accessing health care (7, 19).

Our finding of an association between increased BMI and asthma prevalence is consistent with many recent studies, both cross-sectional and longitudinal, showing that an increased BMI is a risk for asthma in both children and adults (10, 20–26). It is possible that the association between high BMI and wheezing during exercise that we observed could be due to students who report wheezing during exercise because they perceive shortness of breath due to deconditioning as wheezing. On the other hand, this association may be underestimated if students who are overweight are less likely to exercise sufficiently to stimulate wheezing.

Several studies have shown that children raised on farms have less wheezing, asthma, and atopy than children not raised on farms (5, 6, 27). We found that students who reported current farm residence were less likely to report wheezing, wheezing during exercise, ever-diagnosed asthma, and current asthma. A recent survey of schoolchildren in Wisconsin found similar results (4). However, in a study of schoolchildren in two rural Iowa counties, a protective effect due to farm residence was observed in one county, but not in the other (3). The protective effect of farm residence in childhood is thought to be related to microbial exposures associated with livestock farming (28). One of the limitations of our study is that we did not collect information on any potential confounders (e.g., whether the student had any pets) that may also contribute to the protective effect.

In our survey, students were asked only about current residence, which served as a surrogate for early childhood residence, the factor believed to be associated with a lower likelihood of future allergies and asthma. We also assumed that the type of farm that students reported currently living on was the same as that on which they were raised. According to U.S. Census figures, between 1980 and 2000, the rural farm population in Minnesota declined by 50% (29, 30). Since Minnesota families were more likely to have moved off the farm than onto a farm during the period in which the adolescents we studied were growing up, the protective effect may have been underestimated in this study.

We did not see a difference in the prevalence of wheezing and asthma by type of farm (i.e., livestock versus no livestock). However, in this case, type of farm is a crude measure of actual exposures. It is possible, for example, that a farm labeled as crop-only could have had numerous cats, dogs, or even horses to which the student may have had significant exposures.

For those individuals who do go on to develop allergies and asthma, exposures in the farming environment have been shown to be associated with respiratory symptoms, with the greatest effect on those having direct contact with animals (31). The design of this study allowed us to look at the effect of farm exposures not only on farm residents, but also on non-farm adolescents who work on farms. Because of changing farm demographics in Minnesota, young adults who do not live on farms are more likely than they were in the past to be working on farms. We limited our analysis to non-farm residents to see if farm exposures were associated with wheezing and asthma among students who presumably did not experience early childhood farm exposures. While we did not find a difference in asthma prevalence between students who worked on farms and those who did not, we did see more wheezing among non-farm boys working on farms than among non-farm boys not doing farmwork.

The use of self-reported data from adolescents may limit the validity of the data. For example, adolescents may not know about diagnoses of asthma made early in their childhoods. Due to data privacy restrictions, we were not able to use medical records to validate their responses. This limitation might lower the estimates of ever-diagnosed asthma but is unlikely to affect reports of the prevalence of current symptoms (e.g., wheezing). Also, students may have chosen not to report smoking or not to accurately report their height and weight (32). Underreported weights and smoking would tend to weaken the association between smoking and BMI with asthma.

CONCLUSIONS

Asthma is a significant public health issue among adolescents in rural Minnesota; one in 11 adolescents in this region have asthma, and another 8% report symptoms that could represent undiagnosed asthma. Smoking rates accounted for much of the age-associated increase in asthma rates observed among adolescent girls. Consistent with the hygiene hypothesis, rates of asthma were lower among adolescents living on farms but did not differ by the type of farm (livestock versus no livestock). Current smoking and being overweight were associated with wheezing and asthma. Household smoking was associated only with wheezing. Although it is not feasible to move all rural children onto farms, more attention can be given to reducing obesity and smoking in rural teens.

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