Urban–rural differences in asthma prevalence among young people in Canada: the roles of health behaviors and obesity

Joshua A. Lawson, PhD*; Ian Janssen, PhD†; Mark W. Bruner, PhD‡; Koroush Madani, MPH§; and William Pickett, PhD¶

Background: Asthma prevalence has been reported to be lower in rural regions, but the reasons for this are not known.

Objective: To confirm the existence of an urban–rural geographic gradient in asthma prevalence among Canadian youths and to evaluate whether this gradient was mediated by health behaviors.

Methods: Cross-sectional data from 4,726 Canadian youth (grades 6–10) were collected during the 2001–02 Health Behaviour in School-Aged Children survey. Geographic region was categorized as metro (urbanized), non-metro but adjacent to metro, and rural. Asthma was defined via self-report of doctors' diagnoses and at least 1 of: (1) asthma symptoms or (2) a health care visit for asthma in the past year. Health behaviors (diet and physical activity) as well as obesity were also assessed.

Results: Asthma prevalence was lowest in rural regions (metro = 17.7%, non-metro-adjacent = 15.6%, rural = 14.8%). A lower risk of asthma was associated with rural region (adjusted odds ratio [OR] = 0.76, 95% CI = 0.61–0.95) and living in non-metro-adjacent regions (adjusted OR = 0.81, 95% CI = 0.65–1.01). Health behaviors and obesity status did not mediate the association between geographic region and asthma. Being overweight or obese, having a high physical activity level, and exposure to passive smoking independently elevated the risk of asthma, whereas increased consumption of whole milk or vegetables were each protective.

Conclusions: Although asthma prevalence among youth was lower in rural areas, this association was not mediated by health behaviors or obesity. Other exposures, likely environmental, are the logical mechanisms through which rural geographic status is related to lower asthma prevalence.

Ann Allergy Asthma Immunol. 2011;107:220–228.

Affiliations: * Canadian Centre for Health and Safety in Agriculture, University of Saskatchewan, Saskatoon, SK, Canada, and the Department of Medicine, University of Saskatchewan, Saskatoon, SK, Canada; † School of Kinesiology and Health Studies, Queen's University, Kingston, ON, Canada, and the Department of Community Health and Epidemiology, Queen's University, Kingston, ON, Canada; ‡ School of Physical and Health Education, Nipissing University, North Bay, ON, Canada; § Department of Community Health and Epidemiology, University of Saskatchewan, Saskatoon, SK, Canada; ¶ Department of Community Health and Epidemiology, Queen's University, Kingston, ON, Canada, and the Department of Emergency Medicine, Queen's University, Kingston, ON, Canada.

Disclosures: Authors have nothing to disclose.

Funding Sources: Pilot project funding from the Canadian Centre for Health and Safety in Agricultural with program funding from the Canadian Institutes of Health Research. The Canadian version of the World Health Organization-Health Behaviour in School-Aged Children Survey (WHOHBSC) was supported by research agreements with the Public Health Agency of Canada (contract: HT089-05205/001/SS). The WHO-HBSC is a WHO/Euro collaborative study. International Coordinator of the 2001-02 study: Candace Currie, University of Edinburgh, Scotland; and Data Bank Manager: Oddrun Samdal, University of Bergen, Norway. This publication reports data solely from Canada (Principal Investigator in 2001/02: William Boyce). The study reported herein was supported by a pilot grant from the Canadian Institutes of Health Research program funding the Canadian Centre for Health and Safety in Agriculture projects. I.J. holds a Canada Research Chair in Physical Activity and Obesity, and was supported by investigator awards from the Canadian Institutes of Health Research and the Ontario Ministry of Research and Innovation.

Received for publication April 17, 2011; Received in revised form May 31, 2011; Accepted for publication June 18, 2011.

doi:10.1016/j.anai.2011.06.014

INTRODUCTION

Asthma conveys a large impact on the people affected by the disease and on society, especially pediatric populations. Quality of life is lower among children with asthma,[1] and asthma is resource intensive, because it results in a large amount of health care utilization.[2] Asthma has become quite common in children, but the prevalence has been shown to vary geographically.[3,4] A lower prevalence of childhood asthma has been associated with rural residence,[5] but the reasons remain unknown. Explanations could include differences in diagnostic patterns and access to health care, variations in exposures to environmental factors, and differences in body mass index (BMI) status and health behaviors. However, little research is available that identifies which of these explanations is most plausible.

Among the proposed explanations, urban–rural differences in health behaviors and obesity provide a logical explanation that accounts for the observed geographic gradients in the prevalence of asthma. Obesity status and health behaviors, such as physical activity and smoking, are associated with asthma in young people[6–14] and are known to vary across urban and rural populations.[15–17] Consequently, these factors could be a mechanism by which the association between geographic location and asthma is occurring.

Understanding the association between urban–rural status and asthma will help identify factors contributing to variations in asthma prevalence. If an explanation for the urban–rural differences in asthma prevalence can be identified, by focusing on this explanation and associated causative mechanisms, prevention programs or management strategies could be better developed. Also, most existing studies have focused on younger children and not considered youths (preadolescents and adolescents). Given these points, the objectives of our study were to (1) describe the differences in prevalence of asthma between urban and rural populations in a national sample of Canadian youths (preadolescents and adolescents), and (2) identify whether obesity status or health behaviors were associated with asthma and whether these characteristics mediated the association between geographic region and asthma.

METHODS

Study Population and Procedures

Participants were from the Canadian component of the 2001–02 Health Behavior in School-Aged Children (HBSC) survey. The HBSC is an international repeat cross-sectional self-completed survey sponsored by the World Health Organization, designed to provide information about the health and health behaviors of youth. In Canada, participants were students in grades 6 through 10 (approximate ages of 11–15 years). The methodology and procedures used to obtain the sample are outlined elsewhere.[18] Ethical approval was obtained from the Queen's University General Research Ethics Board. Consent was obtained at the school board, parent, and student levels. Written consent was provided by the study participants.

Operational Definitions

Asthma. Asthma was defined by a positive response to the question "Has a doctor ever told you that you have asthma?" and a positive response to any of the following events relating to the past 12 months: (1) wheeze, (2) wheeze or cough during or after active play, (3) dry cough at night without a cold, or (4) visiting a doctor, emergency room, or hospital for wheezing.

Geographic Location. A modified version of the Beale urban–rural coding system[19] was used to group youth into 1 of 3 categories based on the postal code of the school that they attended. Because the HBSC is an anonymous survey, residential postal codes were not available. The geographic categories were (1) *Metropolitan regions* (metro), which are considered to be highly urbanized Census Divisions containing, within or partially within a Census Metropolitan Area/Census Agglomeration, a population greater than 50,000; (2) *Non-metropolitan-adjacent regions* (non-metro-adjacent) are "Census Divisions that share a boundary with a Census Metropolitan Area/Census Agglomeration that has a population greater than 50,000;" (3) *Non-metropolitan-non-adjacent regions* (rural) are "Census Divisions that do not share a boundary with a Census Metropolitan Area/Census Agglomeration that has a population greater than 50,000." The original location variable was a 5-category variable in which categories 1 to 3 represented large, medium, and small metro regions. We chose a 3-category classification system to examine the rural gradient of asthma prevalence as well as to keep non-metro-adjacent as a unique group, because we thought this region could represent a unique geographic segment of the population.

Overweight/Obesity Status. Body mass index (BMI, kg/m^2) was calculated from self-reported height and weight. Classifications for overweight and obesity were based on the International Obesity Task Force guidelines and used age- and sex-specific child BMI cutpoints corresponding to adult (at least 18 years of age) cutpoints for overweight and obesity.[20] A 3-category variable was created: not overweight or obese (corresponding to an adult BMI $<$ 25), overweight (BMI $\geq$25 and $<$30), and obese (BMI $\geq$30).

Health Behaviors: Physical Activity. Participants were provided with a definition and common examples of moderate-to-vigorous intensity physical activities (eg, running, brisk walking, biking) and then asked 2 questions: (1) "Over the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?" and (2) "Over a typical or usual week, on how many days are you physically active for a total of at least 60 minutes per day?"[21] Physical activity participation was based on the average of these 2 questions.[21] Participants were categorized into either low (1 day or less per week), moderate (2–4 days per week), or high (5 or more days per week) physical activity categories.

Diet. Participants were asked how many times per week they usually eat or drink a number of specific food types including vegetables, fruits, and types of milk. Responses for each food type were classified into low (never or less than once per week), moderate (at least once a week but less than once a day), and high (at least once per day) categories.

Personal Smoking. Personal smoking status was defined based on the question "How often do you smoke tobacco at present?" Personal smoking status was then categorized as daily (every day), occasional (not every day), and none (I do not smoke).

Passive Smoking Exposure. Passive smoking exposure was defined based on the parental smoking and the child's best friend's smoking status. The mother's, father's, and best friend's smoking habits were assessed using the question "Do any of the following people smoke?" The best friend's smoking status was classified as daily (smokes daily), occasional (smokes sometimes), and none. The mother and father were considered to be smokers if they were occasional or daily smokers, and their smoking statuses were combined to represent parental smoking, which was classified as neither parent smokes, either the mother or father smokes, or both parents smoke.

Additional Confounders. Other potential confounders included age, sex, ethnicity, and socioeconomic status. Socioeconomic status was defined by the family affluence scale and uses categories of family affluence (low, medium, or high).[18]

Analysis

Statistical analyses were conducted using STATA/SE 9.0 for Windows (Stata Corp, College Station, Texas). Multiple logistic regression was used to examine the associations between geographic location and asthma. The statistical model was fitted with geographic location. Other variables were included based on their biological or clinical importance, statistical significance, or the potential for confounding. To account for the clustered sampling design, generalized estimation equations were used, with the cluster being the classroom. After fitting the full model, a mediation analysis approach was undertaken. Each of overweight/obesity statuses and each of the health behavior variables were removed from the full model 1 at a time, and the proportion of the association between geographic location and current asthma explained by these factors was assessed by: $([OR_{\text{full model without mediator}} - OR_{\text{full model}}]/OR_{\text{full model}})*100$. For mediation to occur, a statistically significant association between the primary exposure (urban–rural status) and the outcome (asthma) must be smaller and no longer statistically significant when the mediator is included.[22] We considered a 5% change in the association to be a meaningful difference.

We conducted a sensitivity analysis to assess whether using self-reported height and weight resulted in some bias. We calculated a modified BMI by adding 1.01 to the BMI for boys and to the BMI for girls. These modifications were based on the observed differences in BMI between self-reported height and weight and objectively measured height and weight from a national sample of Canadian adolescents in the same age range as our study population.[23] This modified BMI was then categorized into normal, overweight, and obese as outlined previously. In the sensitivity analysis, we included this modified obesity status variable in place of the original obesity status variable.

RESULTS

The Canadian portion of the 2001–02 HBSC survey included 7,235 students. The analysis for this study was limited to 4,726 (65%) participants, with complete information on the variables of interest. Those participants included in the analyses were older and more likely to have high physical activity but were less likely to have a low score on the family affluence scale, be overweight or obese, have moderate physical activity levels, drink whole milk, have a best friend who smoked daily, and have both parents smoking (Table 1). The questions most responsible for the missing information included height and weight, resulting in missing BMI data (18.9% missing), asthma information (8.1% missing), and information on parents' smoking (8.2% missing).

Of the final sample, 62.1% lived in metro regions, 16.1% in non-metro-adjacent regions, and 21.8% in rural regions. A higher proportion of rural participants were overweight or obese, reported consuming whole milk, were smokers, had a best friend who smoked, and had parents that smoked (Table 2). Physical activity level was highest in metro (highly urbanized) regions and lowest in non-metro-adjacent regions (Table 2).

As illustrated in Figure 1, current asthma was reported in 16.8% of study participants. The prevalence of asthma became progressively lower as the degree of rurality increased: metro (17.7%); non–metro-adjacent (15.6%); rural (14.8%) with a statistically significant difference between rural and metro regions ($P = .04$). However, no differences were seen between geographic regions with respect to reports of wheeze in the past 12 months. Also, among children with asthma, no difference was seen in the proportion of children who reported that they visited a doctor or emergency room for wheeze in the past 12 months or wheeze or cough during or after exercise in the past 12 months. However, children from rural areas were more likely to report dry cough without a cold than children from other regions.

After adjusting for potential confounders (Table 3), participants in non-metro-adjacent regions (odds ratio [OR] = 0.81, 95% confidence interval [CI] = 0.65–1.01; $P = .06$) and rural regions (OR = 0.76, 95% CI = 0.61–0.95; $P = .02$) had lower relative odds of current asthma compared with participants in metro regions. In contrast to rural geographic region, an increased risk of current asthma was associated with being overweight or obese, reporting moderate or high physical activity, and having a best friend who smokes at least occasionally. In each case, we observed an apparent dose–response relationship in the effect estimates. A reduced risk of current asthma also was associated with higher whole milk consumption and higher vegetable consumption.

When repeating the analysis using the modified obesity status variable, the results were similar. Increased risk of asthma was associated with being overweight (OR = 1.61, 95% CI = 1.33–1.93, $P < .001$) or obese (OR = 1.40, 95% CI = 1.05–1.88, $P = .02$). Also, minimal change occurred in the association between geographic region and asthma when including the modified obesity status variable. Rural and non-metro-adjacent both showed inverse associations with asthma (OR = 0.75, 95% CI = 0.60–0.94, $P = .01$; and OR = 0.81, 95% CI = 0.65–1.00, $P = .05$, respectively).

To assess the potential mediating effects of each of overweight/obesity status and health behaviors in the association between geographic region and current asthma, we reran the statistical analyses after removal of overweight/obesity status and each individual health behavior variable (Table 4). For each analysis, the association between rural region with current asthma remained statistically significant, and the association remained relatively stable (<3% change) compared with the base model. Similar consistencies in model findings were observed for the association between non-metro-adjacent region and current asthma.

DISCUSSION

In this national sample of Canadian adolescents, asthma prevalence was lower in rural regions than in metro regions. A negligible portion of this association was mediated by obesity and health behaviors, suggesting that differences in these factors

Table 1. Characteristics of Adolescents Included and Not Included in the Analysis Because of Missing Data

	Included in the Analysis (n = 4,726) %	**Not Included Because of Missing Data (n = 2,509)[a] %**	**Missing Data for the Variable (n = 7,235) %**
Current asthma			
Absent	83.2	84.5	8.1
Present	16.8	15.5	
Geographic region			
Metro	62.1	61.5	0.0
Non-metro-adjacent	16.1	18.0	
Rural	21.8	20.5	
Age group			
<13 years	32.0	51.2	0.0
≥13 years and <15 years	39.2	32.7[†]	
≥15 years	28.8	16.1[†]	
Sex			
Male	45.9	47.3	0.0
Female	54.1	52.7	
Family Affluence Scale			
Low	9.3	13.2	5.1
Medium	39.4	39.2[b]	
High	51.4	47.6[b]	
Ethnicity			
White	82.9	81.2	0.6
Aboriginal	2.0	2.4	
Other	11.0	12.0	
Mixed background	4.2	4.5	
Obesity status			
Not overweight	82.4	77.7	18.9
Overweight	13.1	17.0[b]	
Obese	4.5	5.3[b]	
Physical activity			
Low	8.8	10.9	3.4
Moderate	45.0	46.6[b]	
High	46.2	42.6[b]	
Whole milk consumption			
Low	83.2	77.9	2.5
Moderate	9.0	11.6[b]	
High	7.7	10.6[b]	
Vegetable consumption			
Low	4.5	5.3	2.7
Moderate	53.2	54.3	
High	42.2	40.4	
Personal smoking			
None	88.5	88.9	3.2
Occasionally	6.4	6.2	
Daily	5.1	4.9	
Best friend smokes			
None	85.2	83.7	7.8
Occasionally	7.7	8.2	
Daily	7.1	8.1[†]	
Parental smoking			
None	63.1	59.2	8.2
Mother or father	24.0	22.8	
Both	12.9	18.0[b]	

[a] Sample size may vary for this group (ie, may not add up to 2,509) because of missing data.
[b] $P < .05$ between those included and excluded with the first category as the reference group.

Table 2. Proportion of Obesity Status and Health Behaviors by Geographic Status

	Metro (n = 2,934) %	Non-metro-adjacent (n = 761) %	Rural (n = 1,031) %	Overall (n = 4,726) %
Obesity status				
Not overweight	84.3	79.9	78.8	82.4
Overweight	11.9	14.5	15.5	13.1
Obese	3.7	5.7	5.7[a]	4.5
Physical activity				
Low	52.0	57.7	56.0	53.8
Moderate	42.8	48.9	48.6	45.0
High	48.0	42.3	44.0 [a]	46.2
Whole milk consumption				
Low	84.6	81.9	80.3	83.2
Moderate	8.5	9.5	10.2	9.0
High	6.9	8.7	9.5 [a]	7.7
Vegetable consumption				
Low	4.3	5.0	4.9	4.5
Moderate	52.6	52.0	55.9	53.2
High	43.1	43.0	39.2	42.2
Personal smoking				
None	89.8	85.2	87.3	88.5
Occasionally	5.8	9.1	6.1	6.4
Daily	4.4	5.8	6.6[a]	5.1
Best friend smokes				
None	86.8	81.9	82.8	85.2
Occasionally	7.1	9.3	8.4	7.7
Daily	6.1	8.8	8.7[a]	7.1
Parental smoking				
None	65.5	58.1	59.7	63.1
Mother or father	23.3	25.0	25.2	24.0
Both	11.1	17.0	15.0[a]	12.9

[a] $P < .05$ when comparing the overall proportions of the independent variable along the metro-rural gradient.

do not provide a solid explanation for the association between urban–rural residence and asthma. We also found that several modifiable health behaviors were associated with asthma.

Similar to ours, results from several studies, primarily in younger children, have demonstrated a reduced prevalence of asthma associated with rural residence,[5] although not all studies have identified this association. One US study found asthma prevalence to be similar between metropolitan and nonmetropolitan regions.[24] The US study, however, included adults, which may have resulted in a lower prevalence of asthma than seen in our study, as well as minimized geographic differences, which might have been observed if the analysis were limited to children.

Because obesity status and the health behaviors did not mediate the association between asthma and geographic region, other existing hypotheses must be considered. A lower prevalence of asthma in rural areas may be occurring because asthma remains underdiagnosed.[25] Within our sample, reported access to medical care for wheeze (doctor's visits, hospitalization, emergency room visits) between metro and rural regions was similar. Although this does not necessarily indicate equal access to health care between regions, it does demonstrate that those adolescents with asthma reported obtaining care from the same facility types.

The environment is a likely mechanism through which the association between geographic region and asthma is operating, although the putative environmental exposures that account for the observed differences have yet to be identified but may include exposure to microbiological components.[26,27] Because the HBSC was not designed specifically for respiratory disease, we were unable to assess the impact of environmental factors other than active and passive smoking exposure.

Obesity and several health behavior patterns were independent predictors of asthma and exhibited a dose–response relationship, strengthening confidence in these observations. Minimal research has been done into the associations between obesity status and health behaviors with asthma in rural populations. Similar to asthma, the prevalence of obesity has risen among children in recent decades.[28] Negative respiratory health outcomes have been associated with obesity, although these associations have often depended on other personal characteristics.[6-8] We expand on previous studies by showing that BMI status is a risk factor for asthma irrespective of location of residence and after controlling for activity and dietary factors.

The association between physical activity and asthma/wheeze has been studied infrequently, with inconsistent associations being reported.[9–11] More asthma occurs in physi-

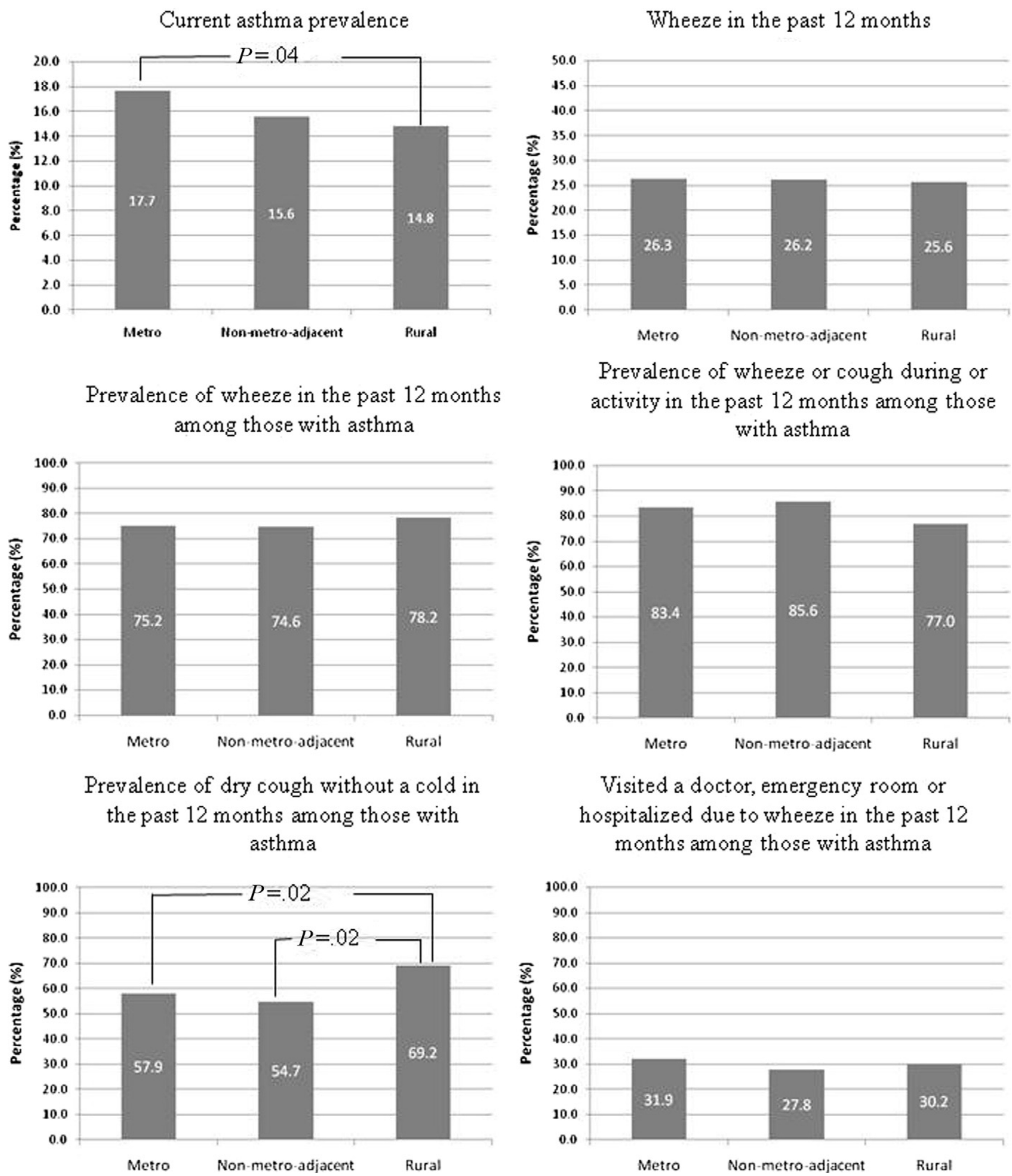

Figure 1. Prevalence of asthma, current wheeze, and health care utilization by geographical region.

Table 3. Distributions and Results of Multivariate Logistic Regression Analysis Examining Possible Determinants of Current Asthma Among Young People in Canada[d]

	No Current Asthma (n = 3,934) %	Current Asthma (n = 792) %	Univariate Odds ratio (95% CI)	Adjusted§ Odds ratio (95% CI)[d]
Geographic region				
Metro	61.4	65.7	1.00	1.00
Non-metro-adjacent	16.3	15.0	0.86 (0.70–1.06)	0.81 (0.65–1.01)[a]
Rural	22.3	19.3	0.80 (0.65–0.99)[b]	0.76 (0.61–0.95)[b]
Obesity status				
Not overweight/obese	83.3	78.0	1.00	1.00
Overweight	12.5	16.2	1.39 (1.13–1.70)[c]	1.40 (1.14–1.73)[c]
Obese	4.2	5.8	1.47 (1.08–2.02)[b]	1.45 (1.05–2.00)[b]
Physical activity				
Low	9.1	7.1	1.00	1.00
Moderate	45.1	44.6	1.29 (0.96–1.73)[b]	1.39 (1.03-1.88)[b]
High	45.8	48.4	1.38 (1.04–1.83)[b]	1.51 (1.12–2.03)[c]
Whole milk consumption				
Low	82.6	86.5	1.00	1.00
Moderate	9.3	7.8	0.81 (0.61–1.09)	0.79 (0.58–1.06)
High	8.2	5.7	0.67 (0.50–0.89)[c]	0.66 (0.50–0.89)[c]
Vegetable consumption				
Low	4.1	6.6	1.00	1.00
Moderate	53.5	51.9	0.61 (0.43–0.87)[c]	0.65 (0.46–0.92)[b]
High	42.3	41.5	0.63 (0.44–0.88)[c]	0.68 (0.48–0.96)[b]
Personal smoking				
None	89.2	85.0	1.00	1.00
Occasionally	6.1	7.7	1.33 (0.97–1.82)[b]	1.10 (0.79–1.53)
Daily	4.7	7.3	1.66 (1.21–2.28)[c]	1.04 (0.70-1.55)
Best friend smokes				
None	86.3	79.4	1.00	1.00
Occasionally	7.3	9.7	1.43 (1.09–1.87)[c]	1.37 (1.03–1.82)[b]
Daily	6.4	10.9	1.86 (1.41–2.45)[c]	1.77 (1.26–2.48)[c]
Parental smoking				
None	63.9	59.1	1.00	1.00
Mother or father	23.7	25.4	1.16 (0.95–1.40)	1.09 (0.89–1.33)
Both	12.4	15.5	1.34 (1.08–1.67)[c]	1.20 (0.96–1.51)

[a] $P < .10$.
[b] $P < .05$.
[c] $P < .01$.
[d] Adjusted for each variable in the table as well as age group, sex, Family Affluence Scale, and ethnicity.

cally active children because active children exert themselves enough to wheeze, leading the child to see a physician, who then may diagnose the child with asthma.[29] Another explanation could be that higher asthma prevalence associated with high physical activity could be attributable to a combined effect with air pollution exposure.[30]

Our results showing a protective effect of fruit and vegetable consumption confirm previous observations.[31,32] Previous studies have shown that type of milk consumed is associated with asthma and allergic disease and that farm or unpasteurized milk may be 1 of the mechanisms by which asthma is reduced in rural/farming environments.[33,34] However, from the information we collected, we were unable to determine whether whole milk would be interpreted as unpasteurized, farm, or raw milk, and so further investigation into this association is required.

Tobacco smoke exposure is a well-studied risk factor for childhood asthma, with negative respiratory health outcomes being reported.[12–14] Interestingly, parental smoking exposure in our study population was not related to the presence of asthma, whereas exposure to a best friend who smoked was associated with asthma. This is consistent with findings from a previous study, which showed that exposure from outside the home had stronger associations than home sources in predicting cotinine, a metabolite of nicotine used to quantify smoking exposure, in teenagers.[35]

Limitations of our study warrant comment. The information collected was self-reported on a questionnaire. However, the information was collected using a standardized questionnaire that has been used internationally. Because no gold standard exists for the diagnosis of asthma, questionnaire report of a doctor's diagnosis of asthma is often used in

Table 4. Association (Odds Ratio [95% confidence intervals]) Between Geographic Region and Current Asthma After Adjustment for Obesity and Six Health Behaviors, Then Removal of Each Factor to Explore Potential Mediation[a]

Model	Metro (Reference Category)	Nonmetro Adjacent Odds Ratio (95% CI)	Rural Odds Ratio (95% CI)	% Change from Base Model—Non-metro adjacent	% Change from Base Model—Rural
Base model[a]	1.00	0.81 (0.65–1.01)	0.76 (0.61–0.95)		
Basic model with the following removed 1 group at a time					
Obesity status	1.00	0.82 (0.66–1.02)	0.77 (0.62–0.96)	1.2	1.3
Physical activity	1.00	0.81 (0.65–1.00)	0.76 (0.61–0.95)	0.0	0.0
Whole milk consumption	1.00	0.80 (0.65–1.00)	0.75 (0.60–0.93)	−1.2	−1.3
Vegetable consumption	1.00	0.81 (0.65–1.01)	0.76 (0.61–0.95)	0.0	0.0
Personal smoking status	1.00	0.81 (0.65–1.01)	0.76 (0.61–0.95)	0.0	0.0
Best friend's smoking status	1.00	0.82 (0.66–1.02)	0.76 (0.61–0.96)	1.2	0.0
Parental smoking	1.00	0.82 (0.66–1.01)	0.76 (0.61–0.95)	1.2	0.0
All of the above	1.00	0.85 (0.69–1.05)	0.78 (0.63–0.97)	4.9	2.6

[a] Includes geographic region as well as age group, sex, Family Affluence Scale, ethnicity, obesity status, physical activity level, whole milk consumption, vegetable consumption, personal smoking status, best friend's smoking status, and parental smoking.

epidemiological studies. This method has reasonable levels of agreement with other methods of assessment and indeed has been considered the method of choice for large epidemiologic studies.[36] Adolescent reports on respiratory symptoms have been found to be accurately reported by the child and strongly agree with parental reports in terms of asthma diagnoses.[37] Despite this, asthma prevalence could be overdiagnosed in this population given the high asthma prevalence and the self-reported nature of the original data source. However, estimates of asthma prevalence in our study are consistent with those reported in other Canadian studies.[38,39] Also, when conducting a sensitivity analysis using a more conservative definition of asthma, estimates were fairly consistent (data not shown). Investigation of the severity of asthma in rural areas provides a definite focus for future research.

Although a limitation of our study could be the self-reported height and weight, a high correlation tends to exist between self-reported height and weight and measured height and weight,[40] and self-reported measures of height and weight are considered valid measures for population-based epidemiological studies.[41] Our sensitivity analysis suggests that there should be minimal bias in the associations reported. Another limitation was the exclusion of a large proportion of the population because of missing data. Because the general characteristics of the population, including geographic region and current asthma, were similar between those included and excluded, the likely effect of exclusions was a loss of statistical power rather than an inherent selection bias. Finally, because location of residence was based on the school and not the child's home, possibly location of residence could be misclassified.

Our findings have several implications for research and practice. They suggest that health behavior and overweight/obesity status are not mechanisms by which the association between rural residence and asthma operate. Identification of the exposures responsible for the apparent protective effect of rural areas therefore remains a priority. This will aid in describing the causal mechanisms for asthma and may have implications for future prevention and management programs. Our results also suggest the importance of encouraging healthy weight, healthy dietary choices, and avoidance of passive smoking, because these strategies may help reduce the presence of asthma in children and could reduce asthma morbidity, as well as promote a generally healthy lifestyle. Finally, investigation of differences in diagnostic patterns between regions may help to more accurately identify children with asthma. This more appropriate diagnosis could result in better management of asthma and improved quality of life.

In summary, we found that asthma prevalence was lower in rural regions compared with urban regions in a national sample of Canadian preadolescents and adolescents. Differences in the prevalence of asthma between urban and rural locations, therefore, are not limited to younger children. Despite having a lower asthma prevalence in rural areas, a large proportion of rural children have asthma, making this an important problem to consider and manage appropriately in young population groups irrespective of where they live. The mechanisms through which this association is occurring are not through BMI status or health behaviors, suggesting that differences in asthma prevalence between geographic locations may be attributable to other factors.

REFERENCES

1. Merikallio VJ, Mustalahti K, Remes ST, et al. Comparison of quality of life between asthmatic and healthy school children. *Pediatr Allergy Immunol.* 2005;16:332–340.
2. Canadian Institutes for Health Information, Canadian Lung Association, Health Canada, et al. Respiratory disease in Canada. Ottawa, Ontario, 2001.
3. Asher MI, Monteforte S, Bjorksten B, et al. Worldwide time trends in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and

eczema in childhood: ISAAC Phases one and three repeat multicountry cross-sectional surveys. *Lancet.* 2006;368:733–743.
4. 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;12:315–335.
5. Senthilselvan A, Lawson JA, Rennie DC, et al. Stabilization of an Increasing Trend in Physician-Diagnosed Asthma Prevalence in Saskatchewan, 1991–1998. *Chest.* 2003;124:438–448.
6. Chen Y, Dales R, Krewski D, et al. Increased effects of smoking and obesity on asthma among female Canadians: The National Population Health Survey, 1994–1995. *Am J Epidemiol.* 1999;150:255–262.
7. Chen Y, Dales R, Tang M, et al. Obesity may increase the incidence of asthma in women but not in men: longitudinal observations from the Canadian National Population Health Surveys. *Am J Epidemiol.* 2002; 155:191–197.
8. Guerra S, Wright AL, Morgan W, et al. Persistence of asthma symptoms during adolescence: role of obesity and age at onset of puberty. *Am J Respir Crit Care Med.* 2004;170:78–85.
9. Vogelberg C, Hirsch T, Radon K, et al. Leisure time activity and new onset wheezing during adolescence. *Eur Resp J.* 2007;30:672–676.
10. Nystad W. The physical activity level in children with asthma based on a survey among 7–16 year old children. *Scand J Med Sci Sports.* 1997;7:331–335.
11. Nystad W, Nafstad P, Harris JT. Physical activity affects the prevalence of reported wheeze. *European Journal of Epidemiology.* 2001;17: 209–212.
12. Cook DG, Strachan DP. Parental smoking and prevalence of respiratory symptoms and asthma in school age children. *Thorax.* 1997;52: 1081–1094.
13. Cook DG, Strachan DP, Carey I. Parental smoking and spirometric indices in children. *Thorax.* 1998;53:884–893.
14. Strachan D, Cook G. Parental smoking and childhood asthma: longitudinal and case-control studies. *Thorax.* 1998;53:204–212.
15. Bruner MW, Lawson JA, Pickett W, et al. Rural Canadian adolescents are more likely to be obese compared with urban adolescents. *International Journal of Pediatric Obesity.* 2008;3:205–211.
16. Mitura V, Bollman R. Health status and behaviours of Canada's youth: a rural-urban comparison: Statistics Canada 2004 Contract No.: Catalogue no. 21-006-XIE.
17. Plotnikoff RC, Bercovitz K, Loucaides CA. Physical activity, smoking, and obesity among Canadian school youth. *Can J Public Health.* 2004; 95:413–418.
18. Currie C, Samdal O, Boyce W, et al. Health behaviour in school aged children: a WHO Cross-National Study (HBSC), Research Protocol for the 2001/2002 Survey: Child and Adolescent Health Research Unit (CAHRU). *University of Edinburgh;* 2001.
19. Vinodrai T. A tale of three cities: the dynamics of manufacturing in Toronto, Montreal, and Vancouver. *Ottawa: Statistics Canada,* 2001.
20. Cole TJ, Bellizzi MC, Flegal KM, et al. Establishing a standard definition for child overweight and obesity worldwide: an international survey. *BMJ.* 2000;320:1240–1243.
21. Prochaska J, Sallis J, Long B. A physical activity screeing measure for use with adolescents in primary care. *Arch Pediatr Adolesc Med.* 2001; 155:554–559.
22. Frazier PA, Tix AP, Barron KE. Testing moderator and mediator effects in counseling psychology research. *Journal of Counseling Psychology.* 2004;51:115–134.
23. Elgar FJ, Stewart JM. Validity of self-report screening for overweight and obesity. *Canadian Journal of Public Health.* 2008;99:423–427.
24. Akinbami LJ, Moorman JE, Liu X. Asthma prevalence, health care use, and mortality: United States, 2005–2009. *National Health Statistics Reports.* 2011;32:1–16.
25. Ownby D. Asthma in rural America. *Ann Allergy Asthma Immunol.* 2005;95 (Suppl 2):S17–S22.
26. 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.
27. Ege MJ, Mayer M, Normand A-C, et al. Exposure to environmental microorganisms and childhood asthma. *N Engl J Med.* 2011;364: 701–709.
28. Shields M. Overweight and obesity among children and youth. *Health Reports.* 2006;17:27–42.
29. Ownby DR, Peterson EL, Nelson D, et al. The relationship of physical activity and percentage body fat to the risk of asthma in 8- to 10-year-old children. *J Asthma.* 2007;44:885–889.
30. McConnell R, Berhane K, Gilliland F, et al. Asthma in exercising children exposed to ozone: a cohort study. *Lancet.* 2002;359:386–391.
31. Chatzi L, Apostolaki G, Bibakis I, et al. Protective effect of fruits, vegetables and the Mediterranean diet on asthma and allergies among children in Crete. *Thorax.* 2007;62:677–683.
32. Nagel G, Weinmayr G, Kleiner A, et al. Effect of diet on asthma and allergic sensitization in the International Study on Allergies and Asthma in Childhood (ISAAC) Phase Two. *Thorax.* 2010;65:516–522.
33. 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.
34. Perkins MR, Strachan DP. Which aspects of the farming lifestyle explain the inverse association with childhood allergy? *J Allergy Clin Immunol.* 2006;117:1374–1381.
35. Jarvis MJ, McNeill AD, Bryant A, et al. Factors determining exposure to passive smoking in young adults living at home: quantitative analysis using saliva cotinine concentrations. *Int J Epidemiol.* 1991;20:126–131.
36. Kemp T, Pearce N, Crane J, et al. Problems of measuring asthma prevalence. *Respirology.* 1996;3:183–188.
37. Hedman L, Lindgren B, Perzanowski M, et al. Agreement between parental and self-completed questionnaires about asthma in teenagers. *Pediatr Allergy Immunol.* 2005;16:176–181.
38. Health Canada. Childhood Asthma in Sentinal Units: Report of the Student Lung Health Study Results 1995–1996. Ottawa: Respiratory Disease Division, Laboratory Centre for Disease Control, 1998.
39. Rennie DC, Lawson JA, Cockcroft DW, et al. Differences in respiratory symptoms and pulmonary function in children in 2 Saskatchewan communities. *Ann Allergy Asthma Immunol.* 2004;92:52–59.
40. Elgar FJ, Roberts C, Tudor-Smith C, et al. Validity of self-reported height and weight and predictors of bias in adolescents. *J Adolescent Health.* 2005;37:371–375.
41. Fonseca H, Silva AM, Matos MG, et al. Validity of BMI based on self-reported weight and height in adolescents. *Acta Paediatr.* 2010;99: 83–88.

Requests for reprints should be sent to:
Joshua Allan Lawson, PhD
3641-103 Hospital Drive
Canadian Centre for Health and Safety in Agriculture
Royal University Hospital
University of Saskatchewan
Saskatoon, SK
Canada S7N 0W8
E-mail: josh.lawson@usask.ca