A Spatial Analysis of Asthma Prevalence in Ontario

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ABSTRACT

Objective: The objective of this paper is to examine spatial patterns of asthma prevalence in the province of Ontario by age and sex between 2002 and 2006.

Methods: We conducted a population-based, ecological-level study using the Ontario Asthma Surveillance Information System Database (OASIS), a validated registry of all Ontario residents with asthma. Data were mapped and analyzed at the sub-Local Health Integration Network (subLHIN) level (n=141). Comparative morbidity figures (CMFs) were calculated and analyzed for local clusters of high and low values ("hot spots" and "cold spots").

Results: There were 1,601,353 individuals identified as having asthma over the study period, representing an overall prevalence rate of 12.93%. Results demonstrate distinct spatial patterns of asthma prevalence across the province which are age- and sex-specific. There was little overlap between asthma hot spots by age group, suggesting that different spatial processes are at play. Patterns of cold spots are consistently seen in the urban and suburban subLHINs in and around Toronto and Hamilton as well as in several of the highly rural northern subLHINs.

Conclusions: Findings illustrate the need for more geographically focused public health and health care planning and resource allocation, and highlight the need for research aimed at understanding the factors that may explain the spatial patterns identified here.

Key words: Asthma; prevalence; spatial analysis; Ontario

La traduction du résumé se trouve à la fin de l'article.

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Asthma is the most common chronic respiratory disease in Canada, representing a significant burden on the individual and society in terms of reduced productivity and increased demands on the health care system.[1] While recent Ontario evidence suggests that asthma incidence is decreasing as disease management and education improves, given the absence of a cure, prevalence continues to increase.[2] Despite the significant burden of asthma, we still know very little about how prevalence varies geographically in Canada and (for the purposes of this study) specifically in Ontario. Prevention programs and health care policies developed based on assumptions of spatial homogeneity may contradict evidence[3-5] and therefore may not lead to improved health outcomes. Research aimed at understanding how asthma prevalence varies geographically is critical for informing the effective allocation of scarce public health resources and can provide clues to understanding determinants of the disease.

Research has shown that factors related to asthma are highly spatially variable in Canadian contexts. Lajoie et al.[6] found strong regional variability in asthma-related emergency department (ED) visits in Quebec, with the highest rates being in urban areas and areas of lower socio-economic status. Significant regional variability was also identified by Lougheed[7] in an analysis comparing hospitalizations to ED visits across Ontario hospital catchment areas. In both studies, the authors acknowledge that outcomes such as ED visits do not reflect asthma prevalence but rather access to community health care and public health services. Studies using survey-derived self-reported measures are also commonly used to make geographic comparisons of asthma prevalence.[3,8,9] These studies, however, are often limited by inadequate sample sizes for detailed analyses, or are highly localized or population-specific in their focus.

There has been a growing interest in developing and mapping asthma prevalence at the population level using administrative health data to improve disease surveillance, inform resource allocation and provide insight into disease aetiology. In contrast to survey data, population-based studies have the potential to yield results that are more generalizable to the population at large. However, reliable prevalence estimates require data that represent more than just one type of health service (e.g., ED visits). One such study conducted by To et al.[5] examined asthma prevalence across Ontario's 14 LHINs, estimated using hospitalization, emergency department visit and physician visit data. Findings revealed a 1.6-fold variation between the lowest rates (in the North) and the highest (in the South). Although limited by the use of large areal units, the findings identified a need for further research aimed at better understanding the geographies of Ontario's asthma burden. The current study attempts to address this need by exploring spatial patterns of asthma prevalence in the province by age and sex using

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a population-based validated asthma registry at a more refined geographic scale.

METHODS

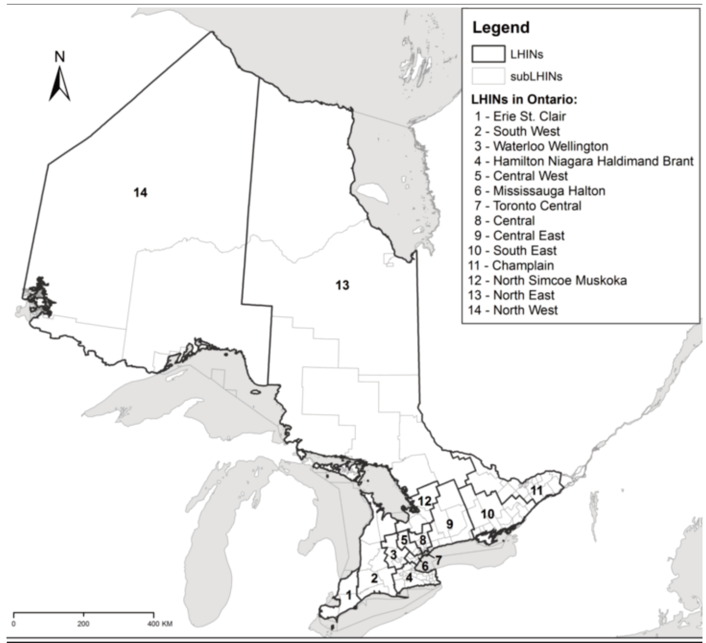
We conducted a retrospective, population-based ecological-level study to assess spatial patterns of asthma prevalence in Ontario over a 5-year period (fiscal years 2002 to 2006) at the sub-Local Health Integration Network (subLHIN) level (version 9). For the purpose of public health and health care planning, Ontario is divided into 14 LHINs which are subdivided into subLHINs (n=141) for more refined local planning (see Figure 1).

Asthma cases were identified through the Ontario Asthma Surveillance Information System Database (OASIS), a validated registry of all Ontario residents with asthma. The registry was generated using: the Ontario Health Insurance Plan (OHIP) which contains information on all fee-for-service billings for physician services as well as emergency department visits, including diagnosis; the Canadian Institute for Health Information Discharge Abstract Database which records the diagnoses for all patients discharged from acute care hospitals; and the Registered Persons Database (RPDB) which contains information on date of birth, sex and location of residence. Databases were linked using encrypted Ontario health insurance numbers. Cases are defined as anyone with at least two asthma-related physician visits within two consecutive years and/or at least one asthma hospitalization since April 1, 1991. This definition, described previously,[2,10,11] yielded 89% sensitivity and 72% specificity in children (<18 years of age) and 84% sensitivity and 76% specificity in adults (>17 years of age). Cases have accumulated since April 1, 1996, and once entered into the database, remain there for as long as the individual is alive and lives in the province. This is consistent with evidence indicating that once diagnosed, asthma may remit but will not resolve.[2,12,13]

To ensure reliable prevalence estimates, average rates were calculated over the study period. Population estimates for all subLHINs (n=141) were not available from any one source, therefore estimates were made using a combination of 2006 weighted population data from the RPDB and 2006 population data from the Ministry of Health and Long-Term Care. While OASIS data go back to 1991, analysis was limited to the 5-year period (fiscal years 2002-2006) to ensure consistent boundary definitions. Descriptive statistics for age- and sex-specific asthma prevalence (unadjusted) were calculated at the provincial and subLHIN level. Statistics include the coefficient of variation (CV), defined as the standard deviation expressed as a percentage of the mean. Using the 2006 Ontario population, rates were then age and sex standardized (direct method) using 10 age categories: 0-4; 5-9; 10-14; 15-19; 20-29; 30-39; 40-49; 50-59; 60-69 and 70+). Following this, comparative morbidity figures (CMFs) were calculated.[14] The CMF is a ratio between the observed directly standardized morbidity rate in a given subLHIN and the expected provincial rate. A CMF value <1 indicates that the rate is below the provincial average and a value >1 indicates that it is above. CMF confidence intervals (at 95%) were calculated (gamma method) and mapped.

To formally test for clusters of high or low CMFs (i.e., "hot spots" and "cold spots"), Local Indicator of Spatial Autocorrelation (LISA) analyses were conducted.[15] Significant spatial autocorrelation indicates a regular pattern in data over space such that a value at a given location depends on, and is similar to, a value of defined spatial neighbours. Global indicators of spatial autocorrelation such as the Moran's I statistic[16] are commonly used to assess this but do not detect localized patterns. The LISA allows for the decomposition of the global indicator into the contribution of each individual observation. A positive value indicates clustering of similarly high values or low values. Neighbour relationships were defined using a queen's contiguity method, expressed in a row-standardized spatial weights matrix.[16] To test for significant departures from zero autocorrelation, a Monte Carlo permutation approach was used (999 permutations at $\alpha<0.05$) and a Bonferroni correction was applied. Analysis was carried out in SAS version 9.2 (SAS Institute Inc., Cary, NC) and GeoDa (v.0.9.5.1).[17]

Figure 1. Study area - LHINs and subLHINs of Ontario, Canada



RESULTS

There were 1,601,353 individuals identified as having asthma in Ontario over the study period (Table 1). The overall prevalence rate was 12.93%, with age-adjusted rates being slightly higher for females than for males at 13.54% and 12.31%, respectively. The highest rates were among males under 20 years, ranging from 18.70% (0-4 years) to 28.02% (10-14 years). The lowest rates are seen among working-age adults where rates were higher for females than for males (e.g., 11.95% vs. 6.99%, respectively, for 50-59 year age group). When disaggregated by subLHIN, the coefficient of variation (CV) shows considerable subLHIN variability that is most pronounced in the youngest age group (e.g., CV=34.02% for females aged 0-4 years) and the oldest age group (e.g., CV=34.41% for males age 70+ years).

Figure 2 shows CMF maps and LISA results for the total population and by sex. Similar patterns of significantly high (p<0.05) CMFs are seen across subLHINs in Eastern Ontario (Champlain LHIN) and near Toronto, where rates are more than 1.2 times the provincial average. The lowest CMFs are seen in the far north and far south of the province, where rates are approximately 1.3 times below the provincial average. Hot spots were detected for both males and females in central Ontario (Central East LHIN) (Figure 2). Among females, one additional cluster was detected to the south of Ottawa (Champlain LHIN). Among males, two clusters are seen in

Table 1. Asthma Prevalence (Unadjusted) and Variability in Ontario by Age and Sex for Fiscal Years 2002 to 2006

		Province Level*		SubLHIN Level†		
Age Group (years)	**Sex**	**Count**	**Prevalence Rate (%)**	**Median Prevalence**	**Range**	**CV‡ (%)**
0-4	Male	65,815	18.70	16.40	7.28-47.39	32.31
	Female	40,729	12.15	10.64	2.86-26.65	34.02
5-9	Male	105,168	26.95	24.45	9.61-52.71	24.57
	Female	71,079	18.99	17.81	5.80-38.69	27.64
10-14	Male	119,396	28.02	27.33	7.12-47.54	20.84
	Female	86,244	21.14	20.62	5.53-41.48	24.93
15-19	Male	87,723	20.23	20.25	3.43-31.89	20.30
	Female	71,943	17.52	17.85	3.13-29.68	21.85
20-29	Male	90,252	10.79	11.19	1.94-16.79	20.89
	Female	110,845	13.50	14.82	4.15-24.67	24.15
30-39	Male	68,000	7.27	7.41	2.02-11.66	20.19
	Female	107,589	11.56	12.31	6.03-21.28	22.08
40-49	Male	73,123	7.15	6.94	1.85-16.90	24.65
	Female	119,051	11.69	11.82	4.41-29.71	23.04
50-59	Male	53,694	6.99	6.80	2.66-21.73	27.70
	Female	94,291	11.95	11.90	6.26-33.83	24.41
60-69	Male	39,306	8.17	7.97	2.63-18.94	27.67
	Female	63,567	12.33	12.13	5.52-35.51	27.53
70+	Male	50,582	10.74	10.17	3.06-40.18	34.41
	Female	82,964	12.49	11.97	5.65-45.88	32.99
All ages	**Male**	**753,055**	**12.31**	**12.23**	**4.20-23.99**	**20.04**
	Female	**848,298**	**13.54**	**13.77**	**4.84-29.08**	**19.54**
Total	**Both sexes**	**1,601,353**	**12.93**	**12.94**	**4.51-26.66**	**19.37**

* Counts and rates based on aggregate province-level data.
† Median, range and CV calculated using ecological subLHIN level data (n=141).
‡ CV=Coefficient of variation.

the suburban and rural areas to the west and north of Toronto. No hot spots were detected for the total population. Several cold spots were identified for all three groups, including one in the far north and several in Southern Ontario.

Figure 3 shows CMF maps and the results of LISA analyses on asthma prevalence for three age groups. One age group was chosen to illustrate each of the following demographics: children, working-age adults, and older adults. For each of the age groups, significantly high ($p<0.05$) CMFs are seen in the east of the province (Champlain LHIN) and north and east of Toronto. Notable in the 30-39 year age group is the large number of significantly high CMF values relative to the 60-69 year age group. Again, the lowest CMFs are found among subLHINs in the North (i.e., North East and North West LHINs) and in the South (e.g., Waterloo Wellington LHIN and Hamilton Niagara Haldimand Brant LHIN (HNHB)). Significant hot spots were detected across all age groups (Figure 3), although there is little overlap. For the 10-14 year age group, there are four small clusters spread out across Southern Ontario: one near Fort Erie and Port Colburn (HNHB LHIN); a second near Peterborough (Central East LHIN); a third in the suburbs around Toronto; and a fourth near Sarnia (Erie St. Claire LHIN). In the 30-39 year age group, there are two large clusters centered in eastern Ontario: one southeast of Ottawa (Champlain LHIN), and a large one centered on Peterborough (Central East LHIN). Among 60-69 year olds, two clusters were identified: one large cluster in the suburbs around Toronto, and a second in Cornwall (Champlain LHIN). Several cold spots are common to all age groups: one centred on Hamilton (HNHB LHIN); a second in the North (North East LHIN); and a third near London (South West LHIN). An additional cold spot centered on Kingston (South East LHIN) is seen in the 60-69 year age group.

DISCUSSION

Using population-level data for the province of Ontario, this study examined spatial patterns of asthma prevalence by age and sex. Before discussing the findings, a few limitations of the study should be addressed. First, this is a descriptive study and as such does not address factors that may explain the spatial patterns identified. Second, the asthma definition used in the OASIS database does not reflect cases where no physician diagnosis has occurred, and as a result less-severe cases might get missed where primary care services are lacking. Also missing from the database are individuals who sought treatment out of province, First Nations populations treated on reserves, and uninsured individuals. Third, COPD (chronic obstructive pulmonary disease) is commonly misdiagnosed in elderly populations as asthma,[18] thereby potentially inflating prevalence rates for the oldest age groups in our study. Finally, the OASIS database only begins in 1991 and as such does not include individuals diagnosed before this year if they have not received treatments since.

Overall prevalence (Table 1) is consistent with other studies using OASIS data but considerably higher than estimates from studies using survey data.[19-21] For example, Garner and Kohen[20] reporting on data from the National Longitudinal Survey of Children and Youth identified 13.4% of children under 12 years as having asthma compared to 19.5% here (data not shown). A partial explanation for this may relate to recall bias in survey data. It can be expected that recently diagnosed incident cases may be well approximated using surveys whereas more remotely diagnosed prevalent cases are missed.[19] Similarly, those with well-controlled asthma who have not experienced symptoms for a lengthy duration may be under-reported. As such, caution should be taken in making direct comparisons between survey and health administrative data.[2,22] While absolute prevalence rates may differ, the relative age and sex patterns here are fairly consistent with other Canadian studies.[2,20,22,23]

This research shows relatively little overlap between asthma hot spots by age group, suggesting that different spatial processes are at play. For example, hot spots in the 10-14 year age group (Figure 3) are centered in areas known for industrial developments and air pollution, including Sarnia (South West LHIN) and Port Colborne

Figure 2. Comparative morbidity figures (CMFs) and local indicators of spatial autocorrelation (LISA) of asthma prevalence by sex in Ontario, 2002-2006

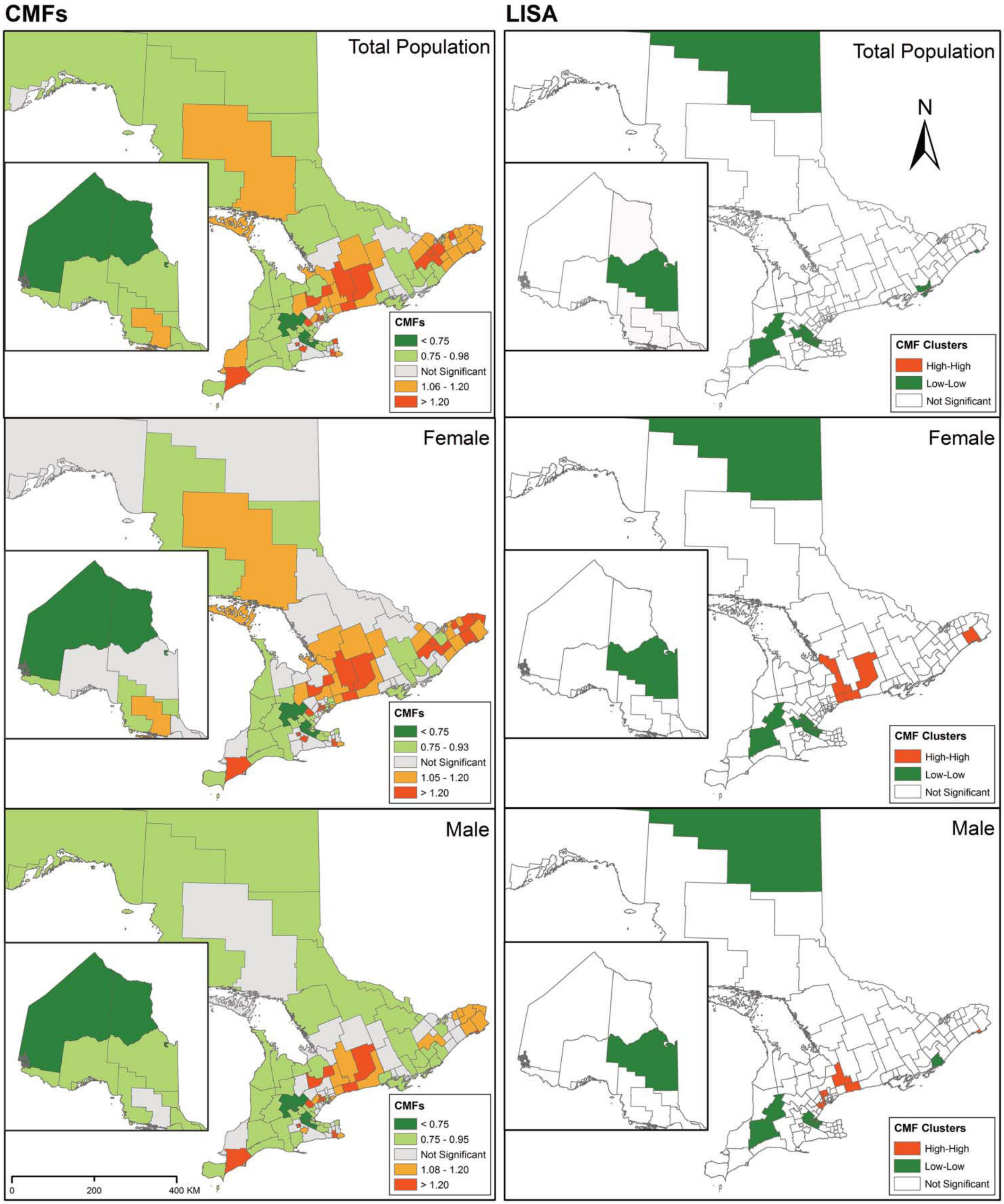
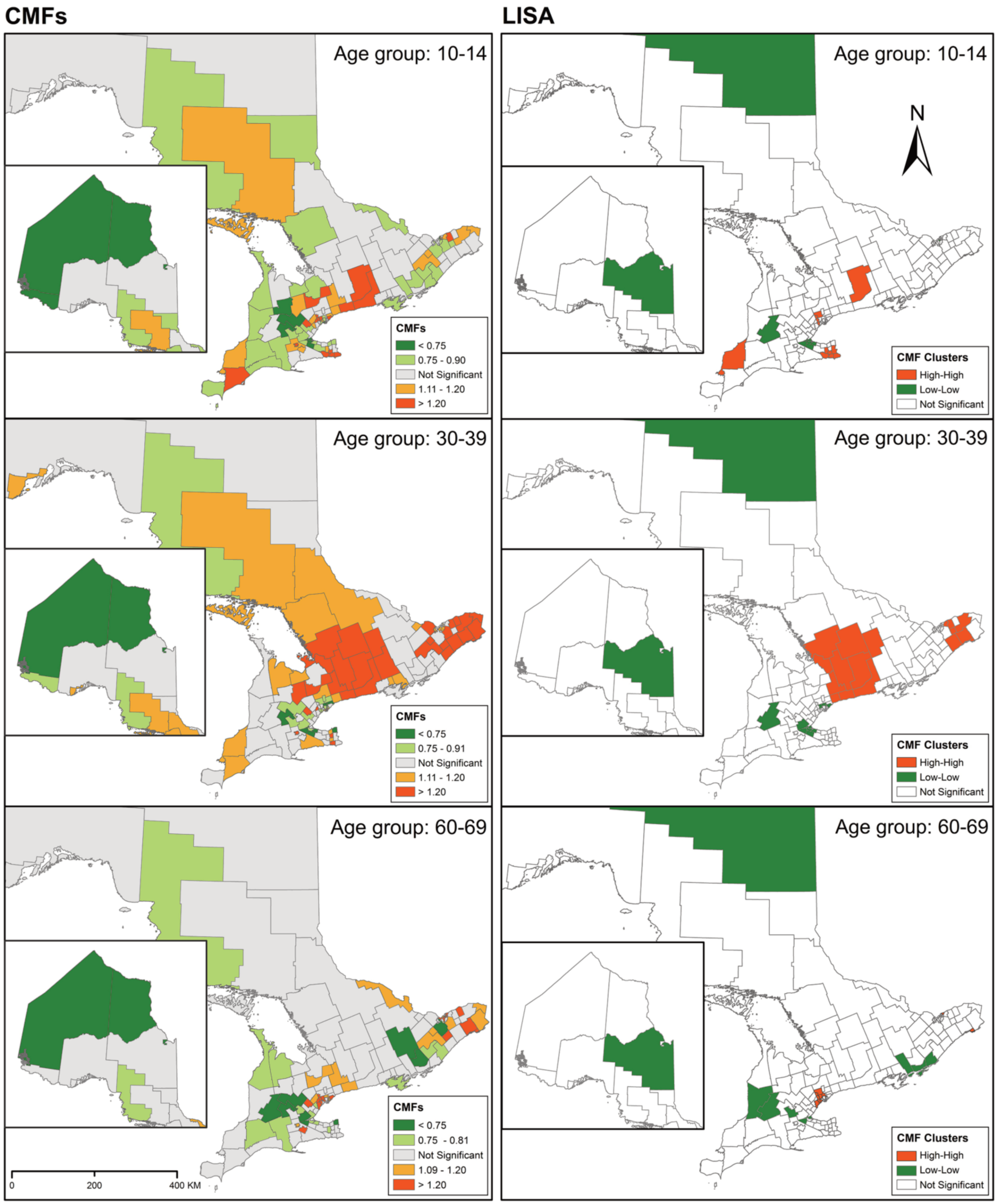


Figure 3. Comparative morbidity figures (CMFs) and local indicators of spatial autocorrelation (LISA) of asthma prevalence by selected age groups in Ontario, 2002-2006



(HNHB LHIN).[24] Air pollution is identified in the literature as an important determinant of asthma, particularly among children.[25,26] On the other hand, the clusters of high CMFs among the 30-39 year age group are centered on rural and less environmentally challenged areas of Central Ontario. It could be hypothesized that occupational or natural environmental factors (i.e., allergens) may be playing a role.[27] Unlike the high CMF clusters, the spatial pattern of cold spots is fairly consistent across groups, with cold spots occurring both in urban/suburban environments in and around Toronto and Hamilton, and in rural areas, including Perth and Huron subLHINs (South West LHIN) and the Cochrane subLHIN (North East LHIN). Low CMFs in the North and rural South may be due in part to poor access to primary health care.[28] In Toronto and Hamilton, cold spots could be expected to reflect the presence of various "protective" factors, including socio-economic or lifestyle factors.[3,29,30] Further research is required to understand these potential relationships.

This research demonstrates the utility of OASIS data for asthma surveillance, in which spatial surveillance is a key component. Results demonstrate that there are marked age- and sex-specific spatial patterns of asthma prevalence across the province. Understanding where the needs are greatest and among whom can be expected to help inform more effective public health and health care programming and resource allocation. These results will also inform a future study examining relationships between spatial patterns of asthma prevalence and potential disease determinants, including air pollution, allergens, socio-economic conditions, occupation and health care.

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RÉSUMÉ

Objectif : Examiner les structures spatiales de la prévalence de l'asthme dans la province de l'Ontario, par âge et par sexe, entre 2002 et 2006.

Méthode : Nous avons mené une étude écologique en population à l'aide de la base de données OASIS (Ontario Asthma Surveillance Information System), un registre validé de tous les résidents de l'Ontario atteints d'asthme. Les données ont été mappées et analysées au niveau des sous-réseaux locaux d'intégration des services de santé (sous-RLISS) (n=141). Nous avons calculé et analysé des indices comparatifs de morbidité pour les grappes locales de valeurs élevées et faibles (« points chauds » et « points froids »).

Résultats : Sur la période de l'étude, 1 601 353 personnes ont été identifiées comme faisant de l'asthme, soit un taux de prévalence global de 12,93 %. Les résultats font état de structures spatiales de prévalence de l'asthme distinctes dans la province, ces structures étant propres à l'âge et au sexe. Il y a peu de chevauchements entre les points chauds de l'asthme par groupe d'âge, ce qui pourrait indiquer que différents processus spatiaux sont en cause. Des points froids sont systématiquement observés dans les sous-RLISS urbains et suburbains de la grande région de Toronto et de Hamilton ainsi que dans plusieurs des sous-RLISS très ruraux du nord de la province.

Conclusion : Ces constatations soulignent que la planification et l'attribution des ressources de la santé publique et des soins de santé devraient se faire davantage sur une base géographique; il faudrait pousser la recherche pour comprendre les facteurs pouvant expliquer les structures spatiales cernées ici.

Mots clés : asthme; prévalence; analyse spatiale; Ontario