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A spatial analysis of COPD prevalence, incidence, mortality and health service use in Ontario

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^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
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Abstract

Background
Risk factors for chronic obstructive pulmonary disease (COPD) include smoking, occupational exposure and air pollution, all of which vary geographically, but relatively little is known about how COPD varies spatially.

Data and methods
This population-based ecological analysis examines physician-diagnosed COPD prevalence, incidence, mortality, and health care services use in Ontario over a 10-year period. Data were mapped and analyzed at the sub-Local Health Integration Network level (n = 141). Comparative morbidity figures were calculated and analyzed for local clusters of high and low rates of COPD health and health service use outcomes.

Results
A total of 722,494 individuals were identified as having COPD over the study period. Clusters of high rates in health outcomes and in most indicators of health service use emerged in northern parts of Ontario and in industrial and more rural agricultural areas. Clusters of low rates were centered in major urban and suburban areas. An exception was COPD-specific physician visits, which were lower in northern areas suggesting greater reliance on acute care.

Interpretation
This study highlights the need for research focused on explaining the spatial patterns identified here.

Keywords
Administrative data, COPD, public health surveillance, spatial analysis

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Chronic obstructive pulmonary disease (COPD) is a leading cause of chronic morbidity and mortality,[1-3] accounting for approximately 4% of deaths worldwide.[4] In Ontario, COPD prevalence increased by almost 65% between 1996 and 2007,[5] and individuals with COPD account for one-fifth to one-third of all health care services used.[6] The impact on individuals and on society, owing to reduced productivity and increased demands on the health care system, is substantial.[3,6-10]

The major risk factors for COPD include smoking,[11] occupational exposure, air pollution, and infections,[12] all of which vary geographically.[11] Despite this, relatively little is known about how COPD varies spatially. Research on geographic distributions of COPD can facilitate the allocation of public health and health care resources.[5,13,14]

Recent North American studies have demonstrated that COPD health outcomes and health care service use vary markedly across geographies.[11,13-16] For example, using zip code tabulation areas and controlling for behavioural risk factors such as smoking, Lipton et al.[11] found geographical variability in COPD-related hospitalizations in California, with higher rates associated with areas of lower socio-economic status, poorer air quality and greater rurality. Joo et al.[15] examined variations and potential determinants of COPD exacerbation (as indicated by hospitalizations, emergency department visits and prescriptions) among registered veterans across 23 Veterans Integrated Service Networks in the United States. Again, geographical variability was apparent, and significant differences remained even when controlling for risk factors (for example, smoking, patient characteristics, comorbidities). The authors concluded that these remaining differences were likely due to regional health care system and treatment characteristics.[15] While these two studies provide insight into the spatial characteristics of COPD, they either focused on a very specific population or on a limited range of health care services.

Few studies have analyzed geographic variations in COPD outcomes in Canada. An exception is Tan et al.[16] who examined COPD prevalence in five Canadian cities. Based on pulmonary function tests, an almost twofold variation in COPD prevalence was apparent across cities, although when the data were adjusted for sex and age differences in the populations, this discrepancy disappeared. Victor et al.[13] analyzed variations in age- and sex-adjusted COPD prevalence, incidence and mortality across Ontario's 14 Local Health Integration Networks (LHINs). They reported that prevalence and incidence varied by more than 20% from the provincial average in several LHINs, but little variation was evident for mortality. They also established the utility of Ontario administrative data for COPD surveillance. These two studies are an important start, but they are limited by their urban focus[16] and use of coarse geographic scales.[13]

This present study analyzes spatial patterns of a range of COPD health outcomes and health service use in Ontario using a validated population-based COPD registry and a more refined geographic scale.

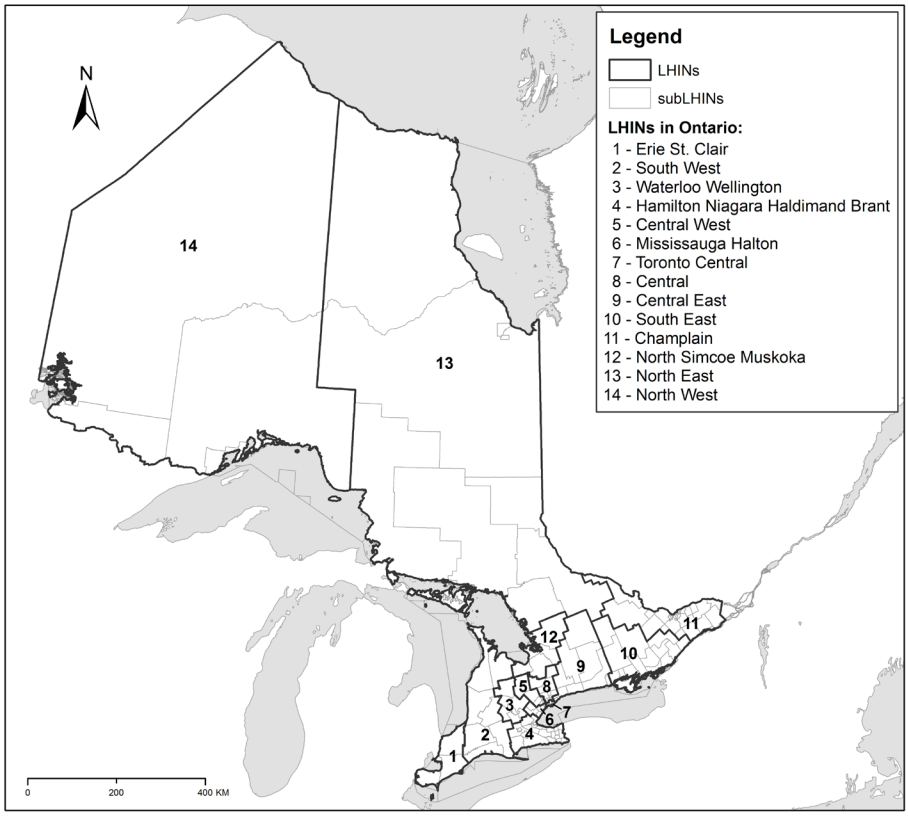
Data and methods

This study examines spatial patterns of physician-diagnosed COPD prevalence, incidence and mortality and COPD-specific health care service use (hospitalizations, emergency department visits not resulting in hospitalization and physician visits) aggregated over a 10-year period (April 1, 2002 to March 31, 2012) for people aged 35 or older, by sex and age group. Those with COPD were identified using Ontario health administrative databases at the Institute for Clinical Evaluative Sciences (ICES), an independent, not-for-profit research institute. Four databases were linked at the individual level to provide a complete health services profile for each individual: (1) the Registered Persons Database (RPDB), which contains demographic information, location of residence and date of death; (2) the Canadian Institute of Health Information Discharge Abstract Database, which contains information on all discharges from acute care hospitals and rehabilitation and chronic care institutions; (3) the Ontario Health Insurance Plan Physician Claims database, which contains information on services provided by fee-for-service physicians and "shadow-billings" for physicians paid under alternate payment plans; and (4) National Ambulatory Care Reporting System databases, which contain information on patient visits to hospitals and community-based ambulatory care.

Individuals were identified as having physician-diagnosed COPD if they met a previously validated case definition of being 35 or older and having had one COPD hospitalization and/or one COPD ambulatory care claim as indicated by the following codes: 491, 492, 496 (International Classification of Diseases, Ninth Revision codes[17]) or J41, J42, J43, J44 (International Classification of Diseases, Tenth Revision codes[18]). This case definition has been found to have a sensitivity of 85.0% and a specificity of 78.4%, when compared with clinical evaluation by a physician.[5,19] People identified as having COPD remained in the study population (*prevalent* cases) until they died or moved out of Ontario. *Incident* cases were defined as individuals who met the COPD case definition but had no COPD-related health care claims in the previous five years. COPD *deaths* were defined as individuals who met the COPD case definition and died from any cause during the study period (all-cause mortality).

The geographic unit of analysis was the Ontario secondary sub-Local Health Integration Network (subLHIN, v.9). Ontario is divided into 14 Local Health Integration Networks (LHINs), health care administrative units that are subdivided into 141 subLHINs (average population = 49,688) (Figure 1).

Figure 1
Ontario Local Health Integration Networks (LHINs) and sub-LHINs



Basic descriptive statistics for each outcome were calculated at the provincial and subLHIN levels by age group (35 to 49, 50 to 64, 65 or older) and sex, data permitting. SubLHIN prevalence and incidence rates were calculated using 2008 weighted population data from the RPDB, 2006 population data at a primary subLHIN level from the Ministry of Health and Long-term Care, and 2002-to-2011 population estimates at the LHIN level from Statistics Canada. Incidence and prevalence rates were calculated by dividing the number of individuals meeting the COPD case definitions by the Ontario population aged 35 or older. Mortality and health service use rates were calculated by dividing the number of individuals who died (all causes) or used the particular health service (COPD-specific) by the prevalent population. To ensure comparable cohort estimates, age- and sex-standardized rates were used for the subLHIN level analyses. Statistics reported include the coefficient of variation (CV), defined as the standard deviation expressed as a percentage of the mean. In accordance with ICES privacy policy, for outcomes where more than 10% of the subLHINs had fewer than 5 cases, age- and/or sex-specific data are not presented.[20]

Comparative morbidity and mortality figures (CMFs)[21] were calculated for each outcome. CMFs are the ratio of the directly observed standardized rate in a given subLHIN to the expected provincial rate. A CMF less than 1.0 indicates that the rate is below the provincial average; a value greater than 1.0 indicates that the rate is above the provincial average. Confidence intervals (99%) for CMFs were calculated (gamma method) and mapped.

For geographical analyses, the CMF is preferable to the more common Standardized Morbidity/Mortality Ratio (SMR). CMFs are calculated using a direct standardization approach with a denominator common to each group or geographic area, whereas SMRs are calculated using an indirect standardization approach with different denominators for each group. While SMRs are useful for comparing morbidity or mortality from different causes within a single group, comparisons between groups have less validity.[22]

To identify clusters of subLHINs with significantly high or low CMFs, Local Indicator of Spatial Autocorrelation (LISA) analyses were conducted.[23] Significant spatial autocorrelation indicates 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[24] do not detect localized patterns. The LISA allows for the decomposition of the global indicator into the contribution of each observation. A positive value indicates clustering of similarly high or similarly low values. Neighbour relationships in the LISA analysis were defined using a queen's contiguity method (first order neighbours) expressed in a row-standardized spatial weights matrix.[24] All analyses were carried out in SAS version 9.2 (SAS Institute Inc. Cary, North Carolina) and ArcGIS (v. 9).

Results

Prevalence

A total of 722,494 individuals in Ontario were identified as having COPD over the 2002-to-2011 period (Table 1). The provincial prevalence rate of COPD

Table 1
Rates (unadjusted) and variability of COPD prevalence, incidence and mortality, by geographic level, age and sex, population aged 35 or older, Ontario, 2002 to 2011 (combined)

	Province level†			SubLHIN level‡		
				Range		
Health outcome, age and sex	Number	Rate (per 1,000)	Median	from	to	Coefficient of variation (%)
Prevalence						
Total	**722,494**	**101.3**	**108.8**	**43.7**	**305.5**	**35.56**
35 to 49						
Men	53,537	35.4	34.4	14.2	153.5	48.99
Women	54,834	36.4	37.8	13.4	207.6	59.34
50 to 64						
Men	121,155	107.0	111.1	45.0	321.5	36.08
Women	117,584	100.6	106.1	41.4	358.1	42.11
65 or older						
Men	183,216	249.1	256.8	118.6	667.7	25.97
Women	192,491	202.2	209.9	93.8	498.6	27.38
Incidence						
Total	**57,158**	**8.2**	**8.4**	**4.0**	**16.9**	**28.84**
35 to 49						
Men	7,277	4.8	4.8	2.1	14.0	39.21
Women	7,130	4.7	4.9	1.7	17.1	47.32
50 to 64						
Men	9,786	8.6	9.0	4.2	15.4	29.11
Women	8,875	7.6	8.0	2.8	15.4	32.21
65 or older						
Men	11,969	16.3	16.8	8.8	43.9	22.71
Women	12,367	13.0	13.5	6.4	22.0	20.71
Mortality						
Total	**31,842**	**4.5**§	**5.0**	**1.4**	**9.6**	**36.14**
Men	16,793	5.0§	5.4	1.5	12.2	36.58
Women	15,091	4.2§	4.7	1.4	8.9	37.42

† counts and rates based on aggregate province-level data

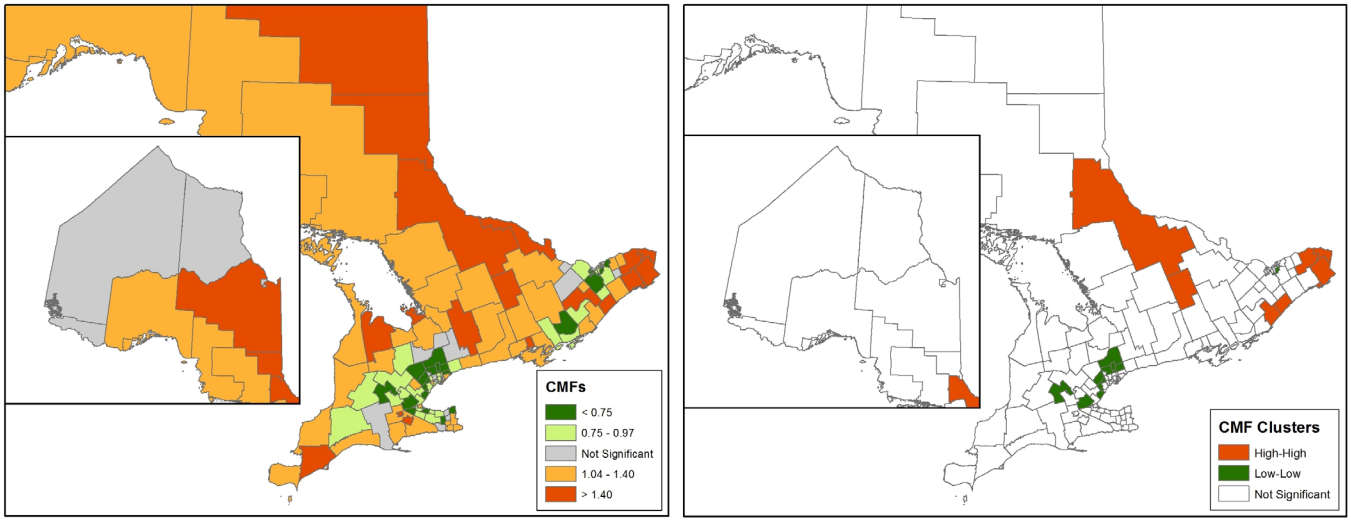
‡ median, range and CV calculated using ecological subLHIN level data (n = 141)

§ based on population aged 35 or older with physician-diagnosed COPD

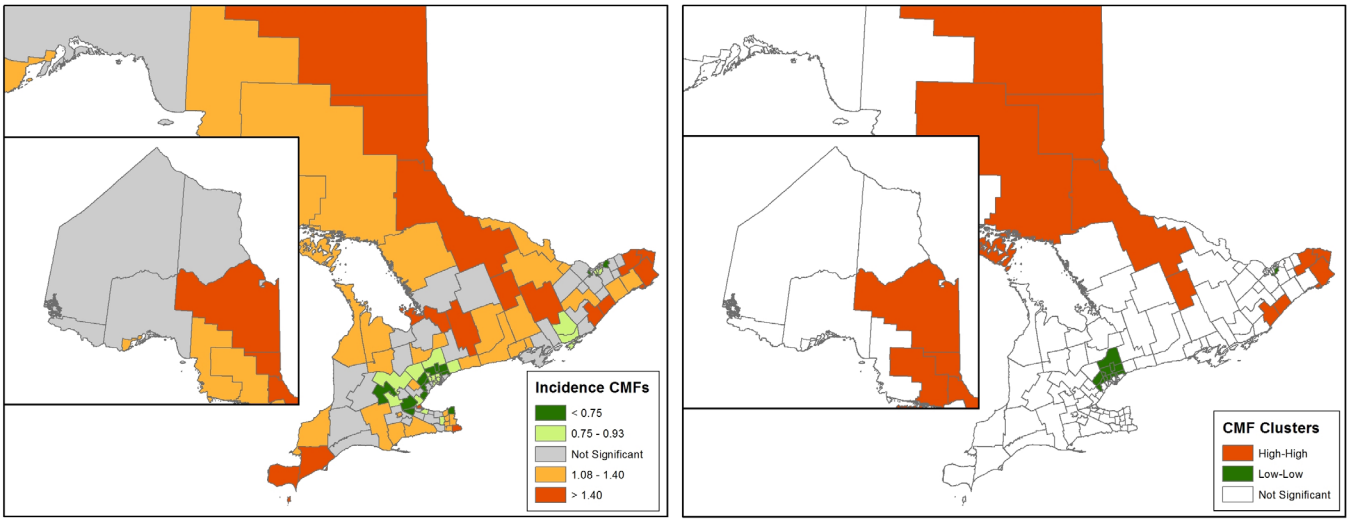
Sources: Registered Persons Database; Discharge Abstract Database; Ontario Health Insurance Plan Physician Claims Database; National Ambulatory Care Reporting System.

Figure 2
Comparative morbidity figures (CMFs) and local indicators of spatial autocorrelation (LISA) of COPD prevalence, incidence and mortality, population aged 35 or older, Ontario, 2002 to 2011 (combined)

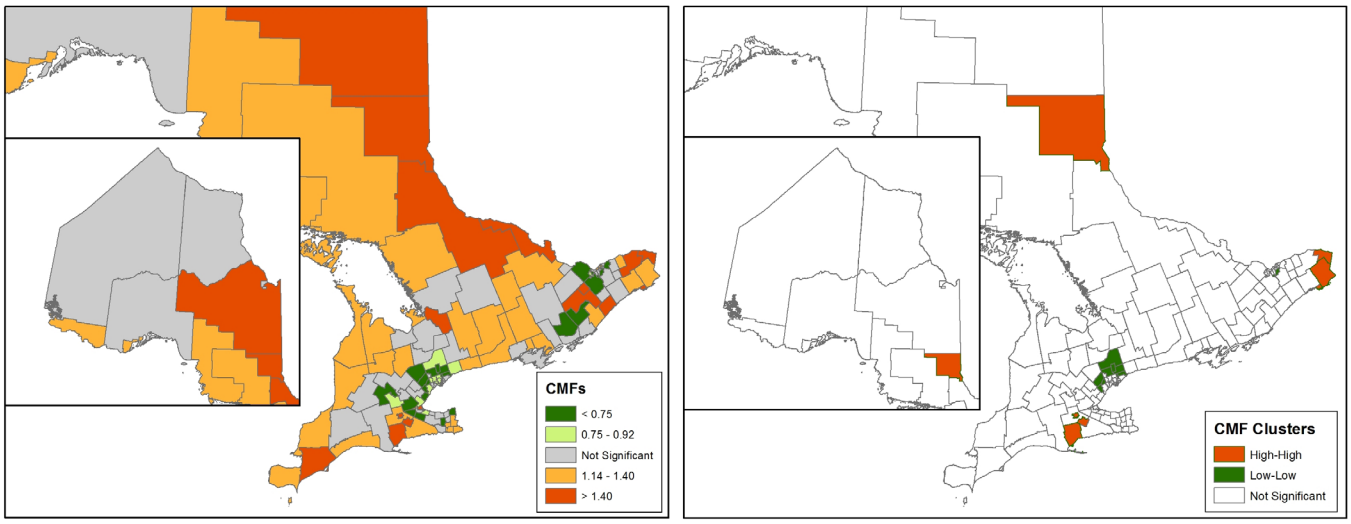
Prevalence



Incidence



Mortality



Sources: Registered Persons Database; Discharge Abstract Database; Ontario Health Insurance Plan Physician Claims Database; National Ambulatory Care Reporting System.

was 103.1 per 1,000 population aged 35 or older, and ranged from 35.4 per 1,000 men aged 35 to 49 to 249.1 per 1,000 men aged 65 or older. Differences by sex were minor, except at age 65 or older—249.1 per 1,000 men versus 202.2 per 1,000 women. When disaggregated by subLHIN, the CV indicates variability at ages 35 to 49 (CV = 48.99% for men; 59.34% for women)

CMFs were significantly above the provincial average (> 1.4; $p < 0.01$) in the rural north (North East LHIN), and in agricultural areas in eastern (Champlain LHIN and South East LHIN) and southern (Hamilton Niagara Haldimand Brant [HNHB] and Erie St. Clair LHIN) Ontario, including the First Nations communities of New Credit and Six Nations (Figure 2). LISA analysis identified clusters of subLHINs with comparatively high prevalence rates in the rural north and in agricultural areas in the east.

The lowest prevalence of COPD was in the urban and suburban areas around Ottawa (Champlain LHIN) and Toronto, where CMFs were significantly below (< 0.75) the provincial average. Clusters of subLHINs with low rates were identified in these areas.

Incidence

During the study period, 57,158 Ontario residents aged 35 or older (8.2 per 1,000) developed COPD (Table 1). In all age groups, incidence rates were higher among men than women, with the highest rate among men aged 65 or older (16.3 per 1,000). When disaggregated by subLHIN, the CV was highest among 35- to 49-year-olds (CV = 47.32% for women; 39.21% for men).

CMFs were significantly high (> 1.4) in the rural north (North East LHIN), agricultural areas in the east and south (Champlain and Erie St. Clair LHINs), and in a number of urban-industrial areas, notably, around the cities of Hamilton and Fort Erie (HNHB LHIN) (Figure 2). Clusters of subLHINs with high rates were detected in the rural north and eastern part of province.

CMFs were significantly low (< 0.75) in suburban areas around Toronto, Kingston and Ottawa. Clusters of subLHINs with low incidence rates were limited to suburban Ottawa and Toronto.

Mortality

Over the 2002-to-2011 period, 31,842 Ontario residents who had COPD died (all-cause). The mortality rate was 4.5 deaths per 1,000 prevalent cases, with men having a higher rate than women (5.0 versus 4.2 per 1,000) (Table 2). The overall CV was 36.14%.

CMFs were significantly high (> 1.4) in the rural north (North East and North Simcoe Muskoka) and in rural, agricultural areas in the east (Champlain and South East) and in the south (Erie St. Clair) and in the First Nations communities of New Credit and Six Nations (HNHB LHIN) (Figure 2). The LISA analysis identified clusters of high mortality rates in eastern and northern areas and in the New Credit and Six Nations communities.

Significantly low CMFs (< 0.75) were found to the north of Kingston (South East LHIN) and in suburban communities around Toronto and Ottawa. Clusters of low rates were identified in Toronto and Ottawa.

Hospitalizations

During the 10-year study period, 29,540 COPD-specific hospitalizations were recorded in Ontario. The overall rate was 40.9 hospitalizations per 1,000 prevalent cases of COPD—43.1 per 1,000 men and 38.9 per 1,000 women (Table 2). Variations by subLHIN were relatively low (CV= 25.55%), and no marked difference emerged between men and women.

CMFs were significantly high (> 1.4) in predominately rural locations in the north (North East and North Simcoe Muskoka LHINs) and in agricultural areas in the south (HNHB and Waterloo Wellington LHINs) and to the west of Ottawa (Champlain LHIN) (Figure 3). LISA analysis revealed a large cluster

Table 2
Rates (unadjusted) and variability for COPD-specific hospitalizations, emergency department visits and physician visits, by geographic level, age and sex, population aged 35 or older with physician-diagnosed COPD, Ontario, 2002 to 2011 (combined)

	Province level†		SubLHIN level‡ (crude rate)			
				Range		
Service use, age and sex	Number	Rate (per 1,000 with physician-diagnosed COPD)	Median	from	to	Coefficient of variation (%)
Hospitalizations						
Total	**29,540**	**40.9**	**40.7**	**19.4**	**80.9**	**25.6**
Men	15,407	43.1	42.7	20.9	82.8	25.3
Women	14,180	38.9	38.2	14.5	78.3	27.2
Emergency department visits						
Total	**14,447**	**20.0**	**19.7**	**5.8**	**59.1**	**55.6**
Men	7,241	20.2	19.5	5.9	61.3	55.7
Women	7,178	19.7	19.0	3.5	58.2	56.9
Physician visits						
Total	**108,934**	**150.8**	**151.5**	**92.0**	**201.3**	**13.2**
35 to 49	8,517	78.6	73.1	36.0	131.8	21.3
50 to 64	29,211	122.4	118.9	74.8	176.2	17.9
65 or older	71,314	189.8	189.1	114.5	25.4	12.5
Men	56,366	157.5	158.1	90.1	214.4	13.4
Women	52,629	144.3	143.3	87.8	190.5	14.7

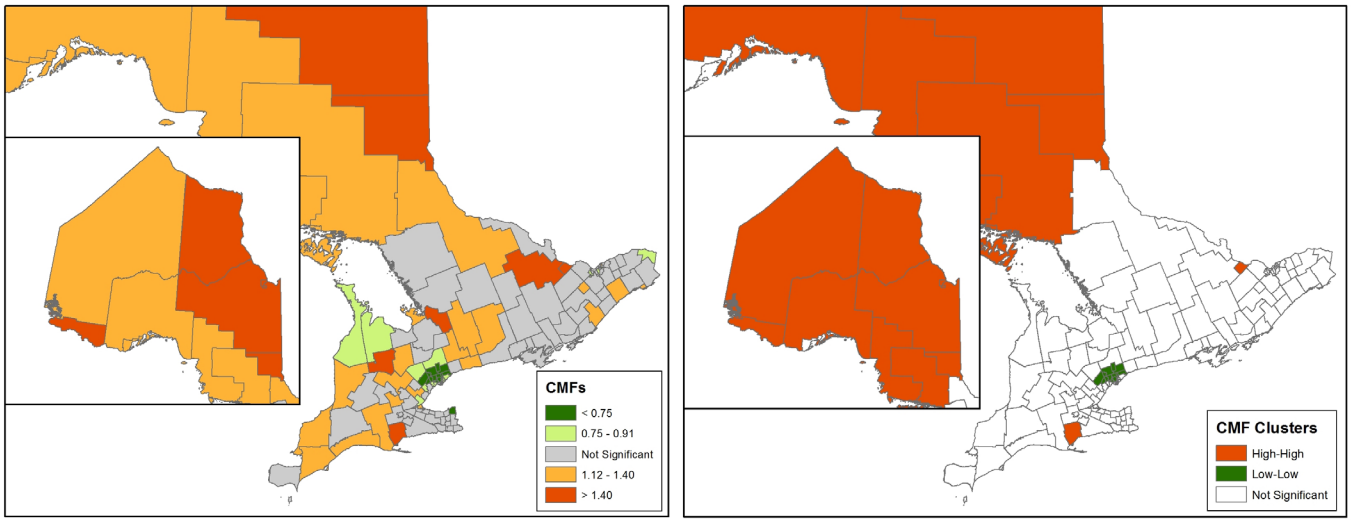
† counts and rates based on aggregate province-level data

‡ median, range and coefficient of variation calculated using ecological subLHIN level data (n = 141)

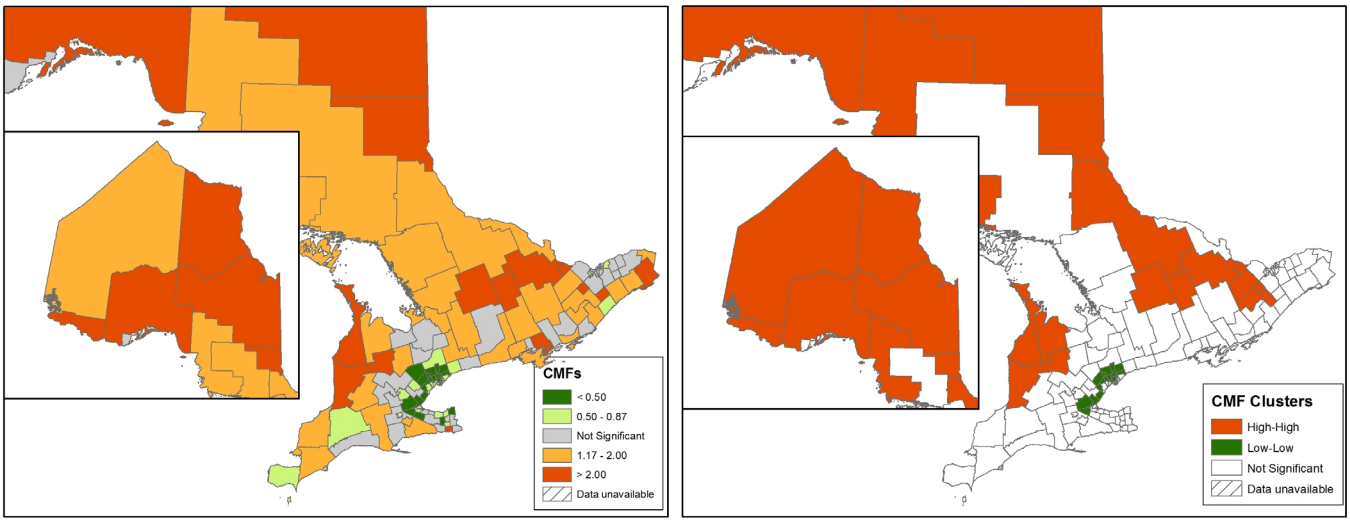
Sources: Registered Persons Database; Discharge Abstract Database; Ontario Health Insurance Plan Physician Claims Database; National Ambulatory Care Reporting System.

Figure 3
Comparative morbidity figures (CMFs) and local indicators of spatial autocorrelation (LISA) of COPD-specific hospitalizations, emergency department visits and physician visits, population aged 35 or older with physician-diagnosed COPD, Ontario, 2002 to 2011 (combined)

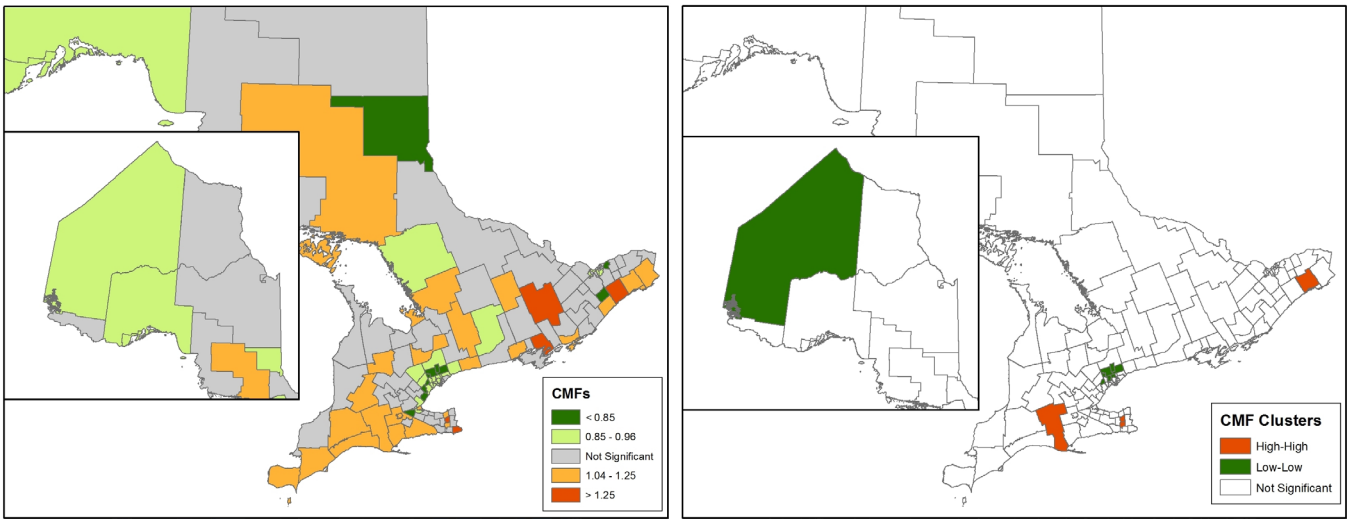
Hospitalizations



Emergency department visits



Physician visits



Sources: Registered Persons Database; Discharge Abstract Database; Ontario Health Insurance Plan Physician Claims Database; National Ambulatory Care Reporting System.

of high rates that covered much of the north; other clusters of high rates were observed in the far south (HNHB LHIN) and to the west of Ottawa. The lowest CMFs (< 0.75) were in the suburban and urban areas around Toronto, and, through LISA analysis, were identified as clusters of low rates.

Emergency department visits

A total of 14,447 COPD-specific emergency department visits took place during the study period, for an overall rate of 20.0 visits per 1,000 prevalent cases—20.2 per 1,000 men and 19.7 per 1,000 women (Table 2). At the subLHIN level, rates varied considerably, with CVs ranging from 55.69% to 56.92%. The highest rates, at over twice the provincial average, were in rural areas throughout the north (North East and North West LHINs), central Ontario (Central East, South East, North Simcoe Muskoka LHINs), and in eastern Ontario (southern parts of the South East and Champlain LHINs).

The LISA analysis identified two clusters of high emergency department visit rates: a large one covering most of the northern part of the province and one in a largely rural area in the northern part of the North West LHIN (Figure 3). The lowest rates—less than half the provincial average—were in more urban areas in and around Toronto, Hamilton and Niagara (HNHB LHIN). One large cluster of low rates centred on urban and suburban areas around Toronto.

Physician visits

Over the study period, 108,934 COPD-specific physician visits were recorded—150.8 visits per 1,000 prevalent cases (Table 2). Seniors (65 or older) with COPD had the highest rate of physician visits: 189.8 per 1,000, which was more than twice the rate for 35- to 49-year-olds with COPD (78.6 per 1,000). SubLHIN variability was low, with CVs ranging from 12.46% for seniors to 21.25% for those aged 35 to 49. CMFs were significantly high (> 1.25) in rural areas of the Champlain and South East LHINs and in the more industrial areas of Fort Erie and Niagara Falls (HNHB LHIN) (Figure 3).

LISA analysis showed clusters of high rates in the Niagara region and in the southern part of the South West LHIN. CMFs were significantly low (< 0.85) in suburban areas around Ottawa and Toronto and rural areas in the north (North West and North East LHINs). One cluster of low rates was detected in the north (North West LHIN), and another, in a suburban area near Toronto.

Discussion

This study examined spatial patterns in of COPD health outcomes and health care service use over a 10-year-period in Ontario. The overall results generally support the findings of other studies,[5,13] with the highest rates among men and the oldest age group. While rates for all measures rose with age, variability in rates, as indicated by the CV, decreased. This implies that younger people, while less likely to develop COPD, are more likely to be influenced by location-specific risk factors.

Compared with the LHIN-level study by Victor et al.,[13] this analysis shows considerable heterogeneity at the subLHIN level, with some areas experiencing consistently higher COPD rates for health outcomes (prevalence, incidence and mortality) and for health service use (hospitalizations and emergency department visits). Given that both studies used the same data source, these differences highlight the potential for more refined geographic data to reveal spatial variations.

Geographic patterns were similar across most COPD measures, including clusters of high CMFs in the north and in agricultural areas in the south and east, and clusters of low CMFs in suburban and urban areas around Toronto and Ottawa. These patterns suggest that similar processes are at work in determining COPD morbidity and mortality. For example, clusters of high CMFs were found in areas such as Port Colborne and Hamilton (HNHB LHIN) where industrial exposure may play a role.[25-27] High rates in rural regions (for instance, Waterloo Wellington and the southern part of HNHB) may be related to environmental exposure associated with agricultural industries.[27-29] As well, socio-economic status tends to be lower in rural than urban areas,[30] and has been associated with a variety of COPD risk factors, including poor nutrition, household crowding, smoking, and occupational exposure.[7,27,31-33] High CMFs for

What is already known on this subject?

- The prevalence of COPD in Ontario increased by almost 65% between 1996 and 2007.
- COPD now accounts for one-fifth to one-third of all health care services used.
- Major risk factors for COPD include smoking, occupational exposure, air pollution, and infections, all of which vary geographically.
- Because relatively little is known about geographic variations in COPD, prevention and health care programs tend to be distributed based on assumptions of spatial homogeneity.

What does this study add?

- Common spatial patterns in most COPD health and health service use outcomes were identified at the population level in Ontario.
- Clusters of high rates of COPD health outcomes and health service use were most consistently identified in northern, industrial and rural agricultural areas; clusters of low rates were identified in major urban and suburban areas.
- COPD-specific physician visit rates were lower in northern areas, suggesting greater reliance on acute care.

COPD incidence, prevalence, mortality, and emergency department visits around the Six Nations of the Grand River First Nations Reserve (HNHB LHIN) may be similarly explained.[34]

Access to health care services may also be related to the spatial patterns identified in this study. For example, physician visits did not follow the trend of other COPD measures in that they were typically lower in northern areas. This implies greater reliance on acute care in the rural north, a finding reported by other authors[35-38] that reflects a shortage of family and specialist physicians.

Limitations

A number of limitations of this analysis must be noted. First, this is a descriptive study and does not address factors that may explain the spatial patterns that were identified. Second, under-diagnosis of COPD is a possibility, because clinical evaluations may not include spirometry,[2,3,39,40] so some less-severe cases may have been missed. Also missing from the data are people who sought treatment out of province, First Nations populations treated on reserves, and uninsured individuals. As well, there is a potential for misdiagnosis in the data, particularly for older people among whom asthma is sometimes confused with COPD.[6,41] Finally, the numerator for health service use rates was the number of individuals using the respective health service rather than the number of events. If individuals had more than one hospitalization, it was not counted; therefore, the rates underestimate COPD-related health service use in Ontario.

Conclusion

This study reveals considerable geographic variability in COPD health outcomes and in most COPD-related health service use measures in Ontario. Clusters of high rates were most consistently identified in northern, industrial and rural agricultural areas; clusters of low rates were limited to the major urban and suburban areas of the province. An exception was COPD-specific physician visits, which were lower in northern areas, suggesting greater reliance on acute care. Information about where and among whom resources are most needed can facilitate public health and health care planning and resource allocation. Findings point to the influence of a complex set of environmental, occupational, socio-economic and health-care-related factors in determining COPD morbidity, mortality and health service use. ■

Acknowledgments

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