
A Population-Based Study

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Background: Chronic obstructive pulmonary disease (COPD) is a preventable and treatable disease with a prevalence of more than 10% worldwide among adults 40 years and older. Whether this amount has been increasing, decreasing, or stable over time remains unknown.

Methods: A longitudinal cohort study using population-based, health administrative data from 1991 to 2007 was conducted in Ontario, Canada. Individuals with COPD were identified using a previously validated health administrative case definition of COPD. Annual COPD prevalence, incidence, and all-cause mortality rates were estimated from 1996 to 2007.

Results: The prevalence of COPD increased by 64.8% between 1996 and 2007. The age- and sex-standardized COPD prevalence rate increased from 7.8% to 9.5%, representing a relative increase of 23.0% (P < .001). The age- and sex-standardized incidence decreased from 11.8 per 1000 adults to 8.5 per 1000 adults, representing a relative decrease of 28.3% (P < .001). Finally, the age- and sex-standardized all-cause mortality rate decreased from 5.7% to 4.3%, representing a relative decrease of 24.0% (P < .001).

Conclusions: Our findings indicate a substantial increase in COPD prevalence in the last decade, with more of the burden being shifted from men to women. Effective clinical and public health strategies are needed to prevent COPD and manage the increasing number of people living longer with this disease.

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Table 1. Age- and Sex-Specific Prevalence of COPD Among Adults 35 Years and Older in Ontario, Canada, in 1996, 2002, and 2007

<table>
<thead>
<tr>
<th>Group</th>
<th>1996</th>
<th>2002</th>
<th>2007</th>
<th>Change From 1996 to 2007, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. With COPD</td>
<td>Population</td>
<td>Prevalence Rate, %</td>
<td>No. With COPD</td>
</tr>
<tr>
<td>Overall, y</td>
<td>731,007</td>
<td>6,444,492</td>
<td>2.1</td>
<td>351,992</td>
</tr>
<tr>
<td>35-49</td>
<td>37,390</td>
<td>129,355,519</td>
<td>2.9</td>
<td>47,223</td>
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<tr>
<td>50-64</td>
<td>54,625</td>
<td>794,420</td>
<td>6.7</td>
<td>88,765</td>
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<tr>
<td>65+</td>
<td>113,077</td>
<td>781,766</td>
<td>14.4</td>
<td>165,716</td>
</tr>
<tr>
<td>All agesb</td>
<td>204,992</td>
<td>2,901,737</td>
<td>6.7</td>
<td>301,719</td>
</tr>
<tr>
<td>Females, y</td>
<td>37,677</td>
<td>129,355,519</td>
<td>2.9</td>
<td>46,146</td>
</tr>
<tr>
<td>35-49</td>
<td>37,239</td>
<td>129,355,519</td>
<td>2.9</td>
<td>46,146</td>
</tr>
<tr>
<td>50-64</td>
<td>63,268</td>
<td>773,311</td>
<td>8.0</td>
<td>93,809</td>
</tr>
<tr>
<td>65+</td>
<td>124,483</td>
<td>573,795</td>
<td>22.8</td>
<td>162,096</td>
</tr>
<tr>
<td>All agesb</td>
<td>225,008</td>
<td>2,646,604</td>
<td>9.1</td>
<td>302,051</td>
</tr>
</tbody>
</table>

Abbreviation: COPD, chronic obstructive pulmonary disease.

a Rates are standardized to the 2001 Ontario population.
b P < .001 for changes in rates over time.
c P < .001 for comparison of rates between age groups.
d P < .001 for comparison of rates between sexes.

METHODS

DATA SOURCES

We based our study on the population of Ontario, which has a large, diverse, multicultural population of more than 12 million residents and constitutes more than one-third of Canada’s population. Ontario has a universal single-payer health care system that covers all physician and hospital services. We searched the Ontario Health Insurance Plan database for physician claims and the Canadian Institute for Health Information database for hospital admissions. Both provide data from April 1, 1991, to March 31, 2008 (fiscal years 1991 to 2007). The Ontario Health Insurance Plan database records all fee-for-service billings for physician services rendered in Ontario and includes the primary diagnosis at each visit. The Canadian Institute for Health Information database records the primary diagnosis and up to 15 secondary diagnoses for all patients discharged from acute care hospitals prior to 2002 and up to 25 secondary diagnoses in 2002 and later years. We linked the data from these databases with the Ontario Registered Persons Database using a unique encrypted Ontario health card number that protects the identity of individuals but allows for the examination of their health services across administrative databases. The Ontario Registered Persons Database also contains demographic, residential, and date of death (if applicable) information for all residents of Ontario. Deaths recorded in the Ontario Registered Persons Database are based on probabilistic linkage of death certificate information. Therefore, to ensure that no deaths were missed, deaths that occurred in-hospital were also recorded and, where discrepancies in dates of death existed between the 2 sources, the hospital date was used. Our study received ethics approval from the institutional review board at Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada.

STUDY POPULATION AND DEFINITION OF COPD

All individuals aged 0 to 99 years living in Ontario from fiscal year 1991 to 2007 were included in the study. Individuals with COPD were identified using a case definition algorithm of 1 or more physician billing claims and/or 1 or more hospital discharges with a diagnosis of COPD as per the following codes: 491, 492, 496 (Ontario Health Insurance Plan and International Classification of Diseases, Ninth Revision codes) or J41, J42, J43, J44 (International Statistical Classification of Diseases, Tenth Revision codes). Individuals also had to be older than 35 years when their claim(s) or discharge(s) occurred. This COPD case definition algorithm was previously validated against a clinical reference standard in a population-based case verification study involving more than 400 individuals with and without COPD. In this study, the case definition algorithm was found to have a sensitivity of 85.0% and a specificity of 78.4%. Once patients were identified as having COPD and included in our analysis, they remained part of our study population throughout the study period unless they died or moved out of Ontario.

ANALYSIS

We used methods consistent with other studies examining prevalence trends of chronic disease. Using our COPD case definition algorithm, we calculated the annual prevalence rates of COPD in the population from fiscal years 1991 to 2007 by dividing the number of patients with COPD who were alive at the end of each fiscal year by the census population estimate of that same year. For years when census measures were unavailable, we used estimated population measures provided by Statistics Canada. We chose to start reporting results starting on April 1, 1996, to allow for sufficient time to identify prior prevalent cases of COPD.

We classified patients as having incident COPD based on the date that they were identified as having COPD according to the case definition algorithm. We presented incidence rates starting in fiscal year 1996 to allow for a look-back period of 5 years to determine whether a patient had any prior COPD records. In cases in which there were prior records, the patient was counted as a prevalent as opposed to an incident case. We chose this period because clinical experience shows that most adults with clinically significant prevalent COPD will contact the health care system at least every 3 years. To calculate
annual incidence rates, we divided the number of individuals who developed COPD in a given year by the number of individuals at risk for COPD (the total population minus the number of people with prevalent COPD in the previous year).

To calculate COPD mortality, the annual numbers of deaths in people with COPD from fiscal years 1996 to 2007 were recorded from the Ontario Registered Persons Database. All deaths were included because COPD has been found to be underestimated as a cause of death on vital statistics death records by around 50%, COPD deaths are often attributed to other diseases like pneumonia and cardiovascular disease, and finally, because specific information about cause of death was unavailable.16,17 We calculated the annual mortality rate by dividing the annual number of deaths in people with COPD by the number of individuals with COPD in each fiscal year.

To compare prevalence, incidence, and mortality rates among different years, we standardized rates for age and sex using 2001 census population estimates in Ontario. We calculated the relative percentage changes in rates between 2 fiscal years using the rate in the earlier year as the reference. We tested for trends over time using the Cochran-Armitage trend test. Finally, we used logistic regression models to test for interactions among age, sex, and fiscal year and because interaction terms were found to be statistically significant, we stratified the analysis by sex and age group. To compare rates between sexes and age groups, we standardized sex-specific rates for age and age-specific rates for sex using 2001 Ontario census data.16 We compared rates among fiscal years, sexes, and age groups using χ² test analyses. We compared percentage changes in rates from fiscal year 1996 to 2007 between sexes and age groups using Cochran–Mantel–Haenszel and Breslow–Day tests.

RESULTS

PREVALENCE

The number of adults with COPD increased by 64.8% from 1996 to 2007 (75.7% in women vs 54.9% in men, P < .001) (Table 1 and Figure, A). Aging of the population could not entirely account for this increase in prevalence because the adult population had a relative increase of only 27.6% during this period. The age- and sex-standardized prevalence increased from 7.8% in 1996 to 9.5% in 2007, which was a 23.0% relative increase (P < .001). Most of the increase was observed in the earlier years between 1996 and 2002 (P < .001). Women had more than twice the increase in age-standardized prevalence compared with men (33.4% vs 12.9%, P < .001). The increase in sex-standardized prevalence was higher in adults aged 50 to 64 years compared with their younger and older counterparts (38.4% compared with −5.9% in adults aged 35 to 49 years and 24.1% in adults ≥65 years, P < .001).

INCIDENCE

The age- and sex-standardized incidence of COPD decreased from 11.8 per 1000 adults in 1996 to 8.5 per 1000 adults in 2007, representing a relative decrease of 28.3% (P < .001). Greater decreases were seen in men compared with women (32.3% and 24.7% respectively, P < .001) and in individuals aged 50 to 64 years compared with the younger and older age groups (31.3% compared with −5.9% in adults aged 35 to 49 years and 24.1% in adults ≥65 years, P < .001).

MORTALITY

Overall, the age- and sex-standardized all-cause mortality rate decreased from 5.7% in 1996 to 4.3% in 2007, representing a 24.0% relative decrease (P < .001). This decrease was greater in men compared with women (25.9% compared to 21.2%, P < .001) and in individuals aged 50 to 64 years compared with the younger and older age groups (31.3% compared with 12.7% and 23.2% respectively, P < .001) (Table 3 and Figure, C).
In this population-based study, we found that, after standardization for age and sex, the prevalence of COPD increased by 23.0%, the incidence of COPD decreased by 28.3%, and the all-cause mortality of individuals with COPD decreased by 24.0% between 1996 to 2007 in Ontario. Most of the increase in prevalence was borne by men. We also found the incidence and all-cause mortality of COPD to be decreasing (more pronounced in men than in women), suggesting that COPD prevention and management strategies are having a benefit.

To the best of our knowledge, there have been no previous large-scale, population-based studies of trends in COPD prevalence. There have been studies, however, that have demonstrated increasing trends in other COPD burden of disease measures such as disability-adjusted life years and, therefore, an increasing prevalence of COPD has been presumed.\(^5\)\(^,\)\(^17\) Prevalence is dependent on incidence and duration of disease. The results of our study demonstrated that the incidence of COPD was decreasing in men more notably than in women. This may partially explain the leveling off of prevalence rates in the later years of our study. The results of our study’s COPD incidence rates were consistent with those reported in previous population-based studies.\(^18\)\(^-\)\(^20\) Smoking is the most important risk factor for COPD, and our incidence trends parallel North American smoking trends in the last 40 years.\(^6\)\(^,\)\(^7\)\(^,\)\(^21\) They also parallel trends in other smoking-related diseases in Canada such as lung cancer and coronary artery disease.\(^22\)\(^,\)\(^23\) Improvements in other COPD risk factors such as occupational exposures and indoor and outdoor air pollutants may have also contributed to improving incidence trends.\(^2\)\(^,\)\(^24\) Prevalence is also dependent on duration of disease, which is influenced by mortality rate, which was also found to be decreasing. This may explain part of the increase in prevalence observed. Aging of the population may explain another part; however, the prevalence of COPD increased faster than the growth of the adult population.

Our prevalence estimates of COPD are lower than those found in the Burden of Obstructive Lung Disease (BOLD) study of 12% to 22%.\(^2\) We hypothesize that this is because the BOLD study identified COPD through screening spirometry while our study identified COPD from claims submitted by physicians, whose use of spirometry has been found to be low and who might not have recognized it until COPD reached more advanced stages.\(^25\) Thus, the current study was more likely to include individuals with clinically significant COPD and miss milder cases. This is consistent with the fact that our prevalence estimates were comparable to BOLD study prevalence estimates of Global Initiative for Chronic Obstructive Lung Disease stage II (moderate) disease or higher, which has been proposed as a threshold for symptomatic and clinically relevant COPD.\(^2\)\(^,\)\(^26\) The prevalence rates we observed also seemed to be consistent with earlier studies that were not based on screening spirometry, where the estimated prevalence of COPD was at 9% to 10%.\(^3\)

The mortality rates and trends in our study differ from previous studies in 2 important ways. First, they are much higher than previously estimated values, and second, they were found to be decreasing over time.\(^4\)\(^,\)\(^5\) These differences are likely because we measured all-cause mortality instead of COPD-specific mortality based on vital statistics records as done in previous studies. Vital statistics records have been found to underestimate the magnitude of COPD mortality by about 50%.\(^14\)\(^,\)\(^15\) Since a significant proportion of patients with COPD die of cardiac causes, it follows that mortality trends would follow those of cardiac disease, which have been decreasing since...
In conclusion, this is the first large, population-based study to examine trends in COPD prevalence, incidence, and all-cause mortality. While we found prevalence rates to be rising, incidence and mortality rates seemed to be decreasing. Finally, we found that the burden of COPD seemed to be shifting from men to women. Our data are important to enable health care providers and policy makers to prepare for the increasing burden of COPD and to demonstrate the positive effects that COPD prevention and management strategies seem to be having on the population. Future research should focus on the identification of high-risk groups or areas for which specific interventions may be required.

Table 3. Age- and Sex-Specific Mortality of COPD Among Adults 35 Years and Older in Ontario, Canada, in 1996, 2002, and 2007

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Deaths</td>
<td>Population With COPD</td>
<td>Mortality Rate, %</td>
<td>No. of Deaths</td>
</tr>
<tr>
<td>Overall, y</td>
<td>429</td>
<td>74,629</td>
<td>0.6</td>
<td>533</td>
</tr>
<tr>
<td>35-49</td>
<td>259</td>
<td>117,811</td>
<td>2.1</td>
<td>310</td>
</tr>
<tr>
<td>50-64</td>
<td>20,906</td>
<td>237,560</td>
<td>9.1</td>
<td>25,863</td>
</tr>
<tr>
<td>65+</td>
<td>23,921</td>
<td>430,000</td>
<td>5.7</td>
<td>29,502</td>
</tr>
<tr>
<td>Females, y</td>
<td>168</td>
<td>37,390</td>
<td>0.5</td>
<td>208</td>
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<tr>
<td>35-49</td>
<td>950</td>
<td>54,255</td>
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<td>1229</td>
</tr>
<tr>
<td>50-64</td>
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<td>7.7</td>
<td>119,173</td>
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<td>204,992</td>
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<td>13,410</td>
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<tr>
<td>Males, y</td>
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<td>324</td>
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<td>35-49</td>
<td>1645</td>
<td>63,286</td>
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<td>50-64</td>
<td>12,209</td>
<td>124,483</td>
<td>10.7</td>
<td>13,890</td>
</tr>
<tr>
<td>65+</td>
<td>14,106</td>
<td>225,008</td>
<td>6.7</td>
<td>16,092</td>
</tr>
</tbody>
</table>

Abbreviation: COPD, chronic obstructive pulmonary disease.

a Rates are standardized to the 2001 Ontario population.
b P < .001 for changes in rates over time.
c P < .001 for comparison of rates between age groups.
d P < .001 for comparison of rates between sexes.

1970.\cite{4,22,27} Decreasing COPD mortality rates are also consistent with decreasing smoking rates and the introduction and widespread use of new therapies that have been shown to improve important outcomes such as hospitalization, exacerbations, and possibly mortality.\cite{7,27}

While men continue to bear most of the burden of COPD, it seems that women are catching up rapidly. Most of the increase in prevalence of COPD was because of increases in women with COPD. Concurrently, decreases in incidence and mortality were more modest in women than those in men. Thus, women continue to be at high risk for COPD.

The strengths of our study are its use of large, comprehensive health administrative databases of the entire population to identify individuals with COPD using a validated algorithm and being able to follow them up over time. The main limitation is our use of physician-diagnosed COPD, which, as discussed earlier, is more likely to detect clinically significant as opposed to milder COPD and, therefore, underestimate prevalence. Nevertheless, we believe that such underdiagnosis would be consistent over the years studied and be unlikely to bias prevalence trends, which were the main outcome of our study. One might hypothesize that increased physician awareness over time could have led to a higher COPD prevalence, but this would run contrary to the decreasing incidence observed. Finally, the physician-diagnosed COPD identified in our study may not be as ideal as spirometry-diagnosed COPD, but it is an outcome of interest because it reflects what is happening in the “real world”—in which routine spirometry screening of the population does not occur—and it captures those who are using health care resources and are responsible for the largest burden of COPD on society. Such a group is of great interest to health care workers and policy makers focused on understanding the burden of COPD and improving the health of the population.
tute of Population and Public Health, and The Public Health Agency of Canada (Dr Gershon); and by The Dales Award in Medical Research from the University of Toronto, Toronto, Ontario, Canada (Dr To); and by the Institute for Clinical Evaluative Sciences (ICES), which is funded by an annual grant from the Ontario Ministry of Health and Long-Term Care.

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REFERENCES

Mislabeling of Figure Key. In the Original Article titled “Trends in Chronic Obstructive Pulmonary Disease Prevalence, Incidence, and Mortality in Ontario, Canada, 1996 to 2007” by Gershon et al, published in the March 22, 2010, issue of the Archives (2010;170[6]:560-565) the figure key on page 562 was mislabeled. The labels for the female and male should be switched; therefore, the circle should have been designated as female; and the diamond, male.