
A Population-Based Study

Andrea S. Gershon, MD, MSc, FRCPC; Chengning Wang, MD, MSc; Andrew S. Wilton, MSc; Roxana Raut, MSc; Teresa To, PhD

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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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 5 years. To calculate

<table>
<thead>
<tr>
<th>Group</th>
<th>No. With COPD</th>
<th>Population</th>
<th>Prevalence Rate, %</th>
<th>No. With COPD</th>
<th>Population</th>
<th>Prevalence Rate, %</th>
<th>No. With COPD</th>
<th>Population</th>
<th>Prevalence Rate, %</th>
<th>Change From 1996 to 2007, %</th>
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<tr>
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<td>35-49</td>
<td>74 629</td>
<td>2 625 049</td>
<td>2.9</td>
<td>93 326</td>
<td>2 876 522</td>
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<td>88 471</td>
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<td>7.4</td>
<td>182 589</td>
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<td>239 290</td>
<td>2 325 083</td>
<td>10.2</td>
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<td>1 355 561</td>
<td>17.9</td>
<td>327 812</td>
<td>1 520 078</td>
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<td>301 719</td>
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<td>360 226</td>
<td>3 667 652</td>
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<td>35-49</td>
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<td>1 299 498</td>
<td>2.9</td>
<td>46 146</td>
<td>1 485 669</td>
<td>3.1</td>
<td>43 641</td>
<td>1 533 259</td>
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<td>17.2</td>
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<td>50-64</td>
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<td>773 311</td>
<td>8.0</td>
<td>93 809</td>
<td>959 647</td>
<td>9.8</td>
<td>120 588</td>
<td>1 140 961</td>
<td>10.5</td>
<td>90.5</td>
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<tr>
<td>≥65</td>
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<td>573 795</td>
<td>22.8</td>
<td>162 096</td>
<td>658 208</td>
<td>25.4</td>
<td>184 288</td>
<td>740 214</td>
<td>25.1</td>
<td>48.0</td>
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<td>2 646 604</td>
<td>9.1</td>
<td>302 051</td>
<td>3 103 524</td>
<td>10.3</td>
<td>348 517</td>
<td>3 414 434</td>
<td>10.3</td>
<td>54.9</td>
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</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.
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. 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. We compared rates among fiscal years, 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, representing a 23.0% 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%, \( P < .001 \)).

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% compared to 24.7% respectively, \( P < .001 \)) and in older (age \( \geq 65 \) years) compared with younger adults (\( P < .001 \)) (Table 2 and Figure, B).

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% decrease (\( P < .001 \)). Greater decreases were seen 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% 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 women. 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. 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. Smoking is the most important risk factor for COPD, and our incidence trends parallel North American smoking trends in the last 40 years. They also parallel trends in other smoking-related diseases in Canada such as lung cancer and coronary artery disease. Improvements in other COPD risk factors such as occupational exposures and indoor and outdoor air pollutants may have also contributed to improving incidence trends. 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%. 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. 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. 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%.

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. 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%. 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...
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>Group</th>
<th>1996 No. of Deaths Population With COPD Mortality Rate, %</th>
<th>2002 No. of Deaths Population With COPD Mortality Rate, %</th>
<th>2007 No. of Deaths Population With COPD Mortality Rate, %</th>
<th>% Change From 1996 to 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall, y</td>
<td>420 74 629 0.6</td>
<td>532 93 369 0.6</td>
<td>466 88 471 0.5</td>
<td>11.0 18.5 −12.7</td>
</tr>
<tr>
<td>35-49</td>
<td>2595 117 311 2.1</td>
<td>3107 182 589 1.7</td>
<td>3469 239 290 1.5</td>
<td>33.7 103.1 −31.3</td>
</tr>
<tr>
<td>50-64</td>
<td>20 906 237 560 9.1</td>
<td>25 863 327 812 7.8</td>
<td>28 221 380 982 7.0</td>
<td>35.0 60.4 −23.2</td>
</tr>
<tr>
<td>≥65</td>
<td>23 921 430 000 5.7</td>
<td>29 502 603 770 4.8</td>
<td>32 156 708 743 4.3</td>
<td>34.4 64.8 −24.0 bc</td>
</tr>
<tr>
<td>All ages a</td>
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<tr>
<td>Females, y</td>
<td>168 37 390 0.5</td>
<td>208 47 223 0.4</td>
<td>199 44 830 0.4</td>
<td>18.5 19.9 −7.3</td>
</tr>
<tr>
<td>35-49</td>
<td>950 54 625 1.7</td>
<td>1229 88 780 1.4</td>
<td>1373 118 702 1.2</td>
<td>44.5 117.7 −32.2</td>
</tr>
<tr>
<td>50-64</td>
<td>8697 113 077 7.7</td>
<td>11 1 156 176 6.8</td>
<td>13 588 166 694 6.1</td>
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<tr>
<td>≥65</td>
<td>9815 204 992 4.8</td>
<td>13 410 301 719 4.2</td>
<td>15 160 360 226 3.8</td>
<td>54.5 75.7 −21.2 d</td>
</tr>
<tr>
<td>All ages a</td>
<td></td>
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<tr>
<td>Males, y</td>
<td>252 37 239 0.7</td>
<td>324 46 146 0.7</td>
<td>267 43 641 0.6</td>
<td>6.0 17.2 −16.3</td>
</tr>
<tr>
<td>35-49</td>
<td>1645 63 286 2.5</td>
<td>1878 93 809 2.0</td>
<td>2096 120 588 1.7</td>
<td>27.4 90.5 −30.7</td>
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<td>50-64</td>
<td>12 209 124 483 10.7</td>
<td>13 890 162 096 9.0</td>
<td>14 633 184 288 8.0</td>
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<tr>
<td>≥65</td>
<td>14 106 225 008 6.7</td>
<td>16 092 302 051 5.6</td>
<td>16 996 348 517 4.9</td>
<td>20.5 54.9 −25.9 d</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.

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.

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Author Contributions: Dr Gershon had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Gershon and To. Acquisition of data: Gershon, Wang, Wilton, and To. Analysis and interpretation of data: Gershon, Wang, Wilton, Raut, and To. Drafting of the manuscript: Gershon. Critical revision of the manuscript for important intellectual content: Gershon, Wang, Wilton, Raut, and To. Administrative, technical, and material support: Gershon and Wang. Study supervision: To.

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1970.4,22,27 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.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 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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Disclaimer: The opinions, results, and conclusions reported in this article are those of the authors and are independent from the funding sources. No endorsement by ICES or the Ontario Ministry of Health and Long-Term Care is intended or should be inferred.

REFERENCES

Mislabeled 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 Gerashon 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.