



Original Contribution

Trends in Asthma Prevalence and Incidence in Ontario, Canada, 1996–2005: A Population Study

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In the 1980s and early 1990s, asthma prevalence increased significantly in most Westernized countries. In more recent years, asthma trends have been less clear, with some studies suggesting that they are still rising and others suggesting that they have stabilized or decreased. A population-based cohort study was conducted to estimate asthma prevalence and incidence trends in one large Canadian province, Ontario. All individuals with asthma living in Ontario, a province of Canada with a multicultural population of approximately 12 million, were identified in universal, population health administrative databases by using a validated health administrative case definition of asthma. Annual asthma prevalence, incidence, and all-cause mortality rates were estimated from 1996 to 2005. During this time, the prevalence of asthma increased by 70.5%. The age- and sex-standardized asthma prevalence increased from 8.5% in 1996 to 13.3% in 2005, a relative increase of 55.1% ($P < 0.0001$). Asthma incidence rates increased in children by 30.0% and were relatively stable in adults. Overall all-cause mortality decreased. Asthma prevalence in Ontario, Canada, has increased significantly. This is attributable, in part, to an increase in the incidence of asthma in children. Effective clinical and public health strategies are needed to prevent and manage asthma in the population.

asthma; incidence; population; prevalence

Asthma is the most common chronic respiratory disease in the world and one of the most common chronic diseases among children (1). In the 1980s and early 1990s, asthma prevalence appeared to increase significantly in most Westernized countries (2). In more recent years, however, trends have been less clear, with some studies suggesting that asthma prevalence has continued to increase and others suggesting that it has stabilized or decreased (2–8). This uncertainty has been made worse by the fact that many asthma prevalence studies, with some notable exceptions, have focused on different specific groups of individuals, such as school children or young adults, who might not be comparable (7, 9, 10). As a result, there is still a lot to be learned about asthma trends in populations overall.

Besides there being gaps in knowledge about trends in prevalence, there is also little known about trends in asthma incidence and all-cause mortality (as opposed to asthma-specific mortality) (11, 12). Incidence is directly and mortality inversely related to prevalence. More knowledge about trends in asthma prevalence, incidence, and all-cause

mortality in the population would be instrumental in helping health-care providers and decision makers anticipate the burden of asthma and optimize clinical and public health strategies for individuals with asthma accordingly.

To fill the above gaps in knowledge, we conducted the current study to estimate overall trends in asthma prevalence, incidence, and all-cause mortality in a large Canadian province. We aimed to quantify the change in asthma prevalence over time and by gender and various age groups.

MATERIALS AND METHODS

Data sources

Our study was based in Ontario, Canada, which has a large, diverse, multicultural population of more than 12 million residents that constitutes more than one-third of Canada's population. Canada is considered a high-incidence country for asthma (1). Ontario has a universal, single-payer health-care system that covers all physician and hospital

services, and the personal health information collected for the administration of this system is available in a few large databases. The Ontario Health Insurance Plan Database contains information on all fee-for-service billings for physician services rendered in Ontario, including a diagnosis, since July 1, 1991. 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. The Ontario Registered Persons Database includes information on gender, birth date, residence postal code, and, if applicable, date of death. Deaths recorded in the Registered Persons Database are based on probabilistic linkage of death certificate information. Therefore, to ensure that no deaths were missed, we also recorded deaths that occurred in the hospital and, where discrepancies in dates of death existed between the 2 sources, the hospital date was used. We linked these databases together on an individual level using an encrypted version of the unique Ontario health insurance number given to all Ontario residents. Such linkage allows for protection of the identities of individuals while examining their health services use across health administrative databases.

Study population and definition of asthma

The Ontario Asthma Surveillance Information System Database is a validated registry of all Ontario residents with asthma that was generated by using the Ontario Health Insurance Plan and Canadian Institute for Health Information health administrative databases described above. For generation of the database, all individuals with asthma were identified by using a previously validated asthma case definition described in detail elsewhere and used in previous studies (13–16). This case definition of at least 2 asthma physician visits within 2 consecutive years and/or at least 1 asthma hospitalization yielded 89% sensitivity and 72% specificity in children (aged 0–17 years) and 84% sensitivity and 76% specificity in adults (aged 18 years or over). Once entered into the database, patients remained part of the asthma population until they moved out of the province or died in order to be consistent with previous evidence indicating that asthma, once diagnosed, may remit but does not resolve (17, 18).

Outcomes

Our primary outcome was change in the age- and sex-standardized prevalence of asthma between fiscal year 1991 (from April 1, 1991, to March 31, 1992) and fiscal year 2005 (from April 1, 2005, to March 31, 2006). Secondary outcomes were changes in the age- and sex-standardized incidence of asthma and all-cause mortality in individuals with asthma over the same time period. All-cause mortality was used because information on disease-specific mortality was not available.

Analysis

We used methods consistent with those of other studies examining prevalence trends of chronic disease using health

administrative data (19–21). Using the asthma case definition, we estimated annual prevalence in the population from fiscal year 1996 to fiscal year 2005 by dividing the number of patients with asthma in each fiscal year by the census population estimate in the corresponding year (22).

We chose to start reporting results in fiscal year 1996 to allow for sufficient time to identify prior prevalent cases of asthma, and we chose the end date of fiscal year 2005 to allow for a 2-year “look forward” period to meet the terms of the validated case-definition algorithm.

Asthma incidence rates were calculated for 5 time periods (1996–1997, 1998–1999, 2000–2001, 2002–2003, and 2004–2005) by dividing the number of incident asthma cases by the number of patient-years of individuals still at risk of developing asthma. Two-year intervals were used so results would be more stable. To confidently distinguish an incident case from a prevalent case, we set a minimum asthma-free observation period of 5 years prior to the incidence date as a requirement. For example, a person meeting the case definition of asthma in fiscal year 2000–2001 must have had no asthma claim during the previous 5 years to be included as an incident case. If he or she had a claim during this time, it was presumed that asthma had previously been considered and that he or she was included as a prevalent, but not an incident, case. The period of 5 years was chosen on the basis of clinical knowledge and previous chronic disease surveillance studies (20, 21, 23). Having a “look-back” period (the same for all individuals so they were treated equally) avoided incidence rates being artificially inflated because of the inclusion of a small number of misclassified prevalent cases. Children born in Ontario after April 1, 1991, were exempt from this rule, because their entire lifetimes were available, which could indicate clearly if they had a prior asthma diagnosis. Incidence of asthma prior to 1996 was not estimated because the 5-year look-back period was not available.

The 5-year look-back period helped to distinguish incident asthma from prevalent asthma during the study period; however, it did not account for individuals diagnosed with asthma prior to 1991; therefore, we applied a second adjustment to our estimates. Because we could not identify individuals with asthma prior to 1991 nor avoid having them possibly show up after a long period of remission as “incident cases,” we applied a correction factor that removed them from our estimates. Specifically, for each 2-year period, we used our asthma cohort to calculate the likelihood of individuals being incident cases prior to our study and then subtracted this amount from our incidence estimate. We calculated the likelihood of individuals being incident cases prior to our study or their previous lifetime risk of developing asthma, by using a modified survival analysis technique described by Beiser et al. (24) and used previously to measure lifetime risk of asthma (refer to Appendix for details) (16). This approach likely overestimated the number of individuals with asthma diagnosed prior to 1991 and provided conservative estimates of the incidence of asthma.

We estimated annual all-cause mortality in the asthma population during fiscal years 1996–2005 by dividing the number of deaths among individuals with asthma by the

Table 1. Age- and Sex-specific Prevalence of Asthma in the Province of Ontario, Canada, in 1996, 2001, and 2005

Group	1996			2001			2005			% Change from 1996 to 2005		
	No. with Asthma	Population, no.	Prevalence, %	No. with Asthma	Population, no.	Prevalence, %	No. with Asthma	Population, no.	Prevalence, %	Individuals with Asthma	Population	Prevalence
Overall												
≤4 years	132,515	754,515	17.6	117,684	708,156	16.6	103,627	672,168	15.4	-21.8	-10.9	-12.2
5-9 years	142,830	759,931	18.8	188,395	797,706	23.6	172,770	768,441	22.5	21.0	1.1	19.6
10-14 years	96,967	739,826	13.1	174,593	803,144	21.7	213,331	835,797	25.5	120.0	13.0	94.7
15-39 years	297,800	4,251,857	7.1	446,157	4,336,701	10.4	566,123	4,400,730	12.9	90.1	3.5	81.5
40-69 years	230,434	3,652,230	6.3	366,864	4,198,081	8.7	467,675	4,711,544	9.9	103.0	29.0	58.3
≥70 years	74,811	924,693	8.0	115,290	1,053,859	10.9	139,051	1,152,730	12.1	85.9	24.7	49.9
All ages ^a	975,357	11,083,052	8.5	1,408,983	11,897,647	11.7	1,662,577	12,541,410	13.3	70.5	13.2	55.1 ^{*,b}
Female												
≤4 years	51,394	367,642	14.0	45,430	348,593	13.0	39,552	328,648	12.0	-23.0	-10.6	-13.9
5-9 years	59,231	370,044	16.0	76,417	390,312	19.6	69,585	377,870	18.4	17.5	2.1	15.0
10-14 years	42,024	360,053	11.7	74,477	391,661	19.0	88,724	407,476	21.8	111.1	13.2	86.6
15-39 years	178,488	2,112,241	8.5	252,603	2,141,815	11.9	302,237	2,181,893	13.9	69.3	3.3	62.3
40-69 years	143,549	1,857,985	7.7	229,902	2,126,861	10.8	292,160	2,384,917	12.2	103.5	28.4	59.0
≥70 years	45,083	555,808	8.1	71,065	620,366	11.5	86,556	668,988	13.0	92.0	20.4	60.1
All ages ^a	519,769	5,623,773	9.1	749,894	6,019,608	12.4	878,814	6,349,792	13.9	69.1	12.9	51.8 ^c
Male												
≤4 years	81,121	386,873	21.0	72,254	359,563	20.1	64,075	343,520	18.7	-21.0	-11.2	-11.0
5-9 years	83,599	389,887	21.4	111,978	407,394	27.5	103,185	390,571	26.4	23.4	0.2	23.2
10-14 years	54,943	379,773	14.5	100,116	411,483	24.3	124,607	428,321	29.1	126.8	12.8	101.1
15-39 years	119,312	2,139,616	5.7	193,554	2,194,886	8.9	263,886	2,218,837	11.8	121.2	3.7	109.5
40-69 years	86,885	1,794,245	4.8	136,962	2,071,220	6.6	175,515	2,326,627	7.5	102.0	29.7	57.0
≥70 years	29,728	368,885	8.0	44,225	433,493	10.2	52,495	483,742	10.9	76.6	31.1	36.0
All ages ^a	455,588	5,459,279	7.9	659,089	5,878,039	10.9	783,763	6,191,618	12.6	72.0	13.4	58.3 ^c

* $P < 0.001$ for comparison of rates over time, from 1996 to 2005.

^a Rates are standardized to the 2005 Ontario population.

^b Rates between ages are standardized by gender to the 2005 Ontario population; $P < 0.001$ for comparison of rates between age groups.

^c Rates between sexes are standardized by age to the 2005 Ontario population; $P < 0.001$ for comparison of rates between sexes.

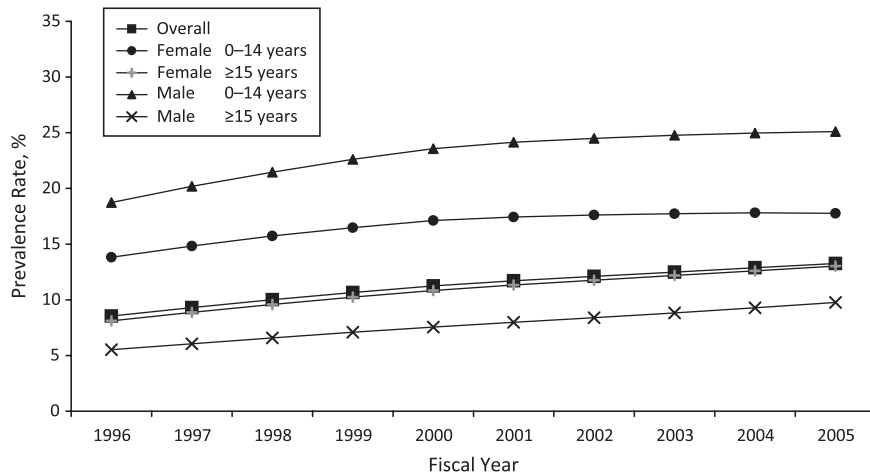


Figure 1. Annual standardized asthma prevalence in the province of Ontario, Canada, overall and by sex and age group, from 1996 to 2005.

number of individuals with asthma in each fiscal year. We used all-cause mortality because information on disease-specific mortality was not available.

To compare prevalence, incidence, and mortality rates over time, we standardized them for age and sex using 2005 Ontario census population estimates. We calculated the relative percentage change in rates between 2 fiscal years using the rate in the earlier fiscal year as the reference. We also 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 significant, we stratified the analysis by age and sex. To compare trends between sexes and age groups, we standardized sex-specific rates for age and age-specific rates for sex using Ontario 2005 census data (25). We compared rates among fiscal years, sexes, and age groups using chi-squared analyses. We compared percentage changes in rates from fiscal year 1996 to fiscal year 2005 between sexes and age groups using Cochran-Mantel-Haenszel and Breslow-Day tests.

Sensitivity analysis

To test the rigor of our results, we reconstructed the asthma cohort using a second previously validated health administrative case definition of asthma shown to have about 11%–12% higher specificity than the case definition used in the primary analysis (84% and 87% specificity in children and adults, respectively). Unfortunately, as is often the case, there was a tradeoff between specificity and sensitivity, so that the sensitivity of this new case definition was about 10% lower than that of the case definition used in the primary analysis (80% and 74% sensitivity in children and adults, respectively) (13–15). We then recalculated change in prevalence.

Ethics statement

Ethics approval was obtained from the institutional review boards at The Hospital for Sick Children and Sunnybrook Health Sciences Centre, Toronto, Ontario.

RESULTS

Asthma prevalence

The number of individuals with asthma increased by 70.5% from 1996 to 2005. This increase was significantly greater than the population growth of 13.2% during the same time period. The age- and sex-standardized prevalence increased from 8.5% in 1996 to 13.3% in 2005, which was a 55.1% relative increase ($P < 0.001$). Most of the increase was seen in the first part of the study period, approaching a plateau in the later part (Table 1; Figure 1).

The sex-standardized increase in prevalence was greatest in adolescents and young adults compared with other age groups ($P < 0.001$), while it appeared to be decreasing in children 4 years of age or less. The age-standardized increase in prevalence was greater in males compared with females ($P < 0.001$). Compared with females, males experienced higher increases in prevalence in adolescence and young adulthood and lower increases at age 70 years or older (Table 1; Figure 1).

Asthma incidence

From 1996 to 1999, the overall age- and sex-standardized incidence rate of asthma increased from 5.0/1,000 person-years to 5.7/1,000 person-years, a relative increase of 14.0% ($P < 0.001$). This increase was mainly due to a 30% increase in children aged 14 years or younger. After 1999, the incidence rates remained relatively stable in children and modestly decreased ($P < 0.001$) in all other age groups (Table 2; Figure 2).

Mortality

The overall age- and sex-standardized all-cause mortality rates were very low. They decreased from 887.6/100,000 individuals in 1996 to 730.0/100,000 individuals in 2005, which was a relative decrease of 17.8% ($P < 0.001$) (Table 3).

Table 2. Age- and Sex-specific Incidence of Asthma in the Province of Ontario, Canada, in 1996–1997, 2000–2001, and 2004–2005

Group	1996–1997		2000–2001		2004–2005		% Change from 1996 to 2005	
	No. with Asthma	Incidence Rate/1,000 Person-Years ^a	No. with Asthma	Incidence Rate/1,000 Person-Years ^a	No. with Asthma	Incidence Rate/1,000 Person-Years ^a	Individuals with Asthma	Incidence Rate
Overall								
≤4 years	51,315	22.4	57,413	31.1	48,430	31.3	–5.6	39.7
5–9 years	46,016	8.8	46,742	11.0	35,832	10.9	–22.1	23.1
10–14 years	208,727	5.2	236,324	5.8	199,482	5.6	–4.4	7.6
15–39 years	50,388	3.3	49,606	3.3	37,480	2.9	–25.6	–13.9
40–69 years	45,098	3.5	50,951	3.7	42,461	2.8	–5.8	–21.2
≥70 years	14,874	4.5	16,463	4.2	12,873	3.2	–13.5	–27.0
All ages ^b	180,905	5.0	205,647	5.7	174,337	5.1	–3.6	1.6
Female								
≤4 years	16,553	19.0	21,308	25.9	20,078	26.3	21.3	38.1
5–9 years	8,487	8.1	10,292	9.9	9,059	9.6	6.7	18.9
10–14 years	6,217	5.4	6,462	5.9	5,969	5.9	–4.0	8.1
15–39 years	31,142	4.2	30,279	4.1	22,959	3.6	–26.3	–14.3
40–69 years	27,822	4.3	30,677	4.8	25,145	3.3	–9.6	–22.6
≥70 years	8,841	4.3	9,776	4.2	7,687	3.4	–13.1	–22.0
All ages ^b	99,062	5.3	108,794	6.0	90,897	5.2	–8.2	–2.8*
Male								
≤4 years	22,960	25.7	30,819	36.0	28,836	36.2	25.6	40.9
5–9 years	10,367	9.6	13,142	12.1	11,800	12.1	13.8	26.5
10–14 years	5,961	5.1	6,604	5.7	5,781	5.4	–3.0	7.0
15–39 years	19,246	2.5	19,327	2.5	14,521	2.2	–24.6	–13.1
40–69 years	17,276	2.7	20,274	2.7	17,316	2.2	0.2	–18.9
≥70 years	6,033	4.7	6,687	4.2	5,186	3.1	–14.0	–33.4
All ages ^b	81,843	4.6	96,853	5.3	83,440	4.9	2.0	6.3*

* $P < 0.001$ for comparison of rates between sexes.

^a Rates are adjusted for the cumulative risk of physician-diagnosed asthma prior to the study period.

^b Rates are standardized to the 2005 Ontario population.

Sensitivity analyses

Using a health administrative case definition of asthma with high specificity (but limited sensitivity) to calculate prevalence trends, we found that the number of individuals with asthma increased by 63.5%. This corresponded to an age- and sex-standardized relative prevalence increase of 44.5%.

DISCUSSION

We conducted a population-based study of all individuals living in Ontario, Canada, and found that, after standardization by age and sex, the prevalence of asthma increased by 55.1% between 1996 and 2005. Most of the increase was seen in the beginning, with trends approaching a plateau in the later years of the study. Even when a definition of asthma with high specificity (but limited sensitivity) was used, the increase in prevalence remained high. Overdiagnosis of

asthma in the later years of the study could not have been responsible for this increase, because overall incidence rates increased by only 1.6%. A 30% increase in the incidence of asthma in children and low mortality overall, however, likely contributed to the increase in prevalence seen. To the best of our knowledge, this is the first large study to examine asthma prevalence trends in an entire population. Such a large increase, especially in children, is concerning, and more research is needed to determine why it is occurring and how it can be reversed. These findings stress the importance of having clinical and public health strategies to effectively prevent and manage this very common disease.

The increasing prevalence and incidence found in our study are consistent with those of others, including one using Statistics Canada data, that have shown similar increasing trends (2, 4–6, 8, 26). They are also consistent with, and appear to be a continuation of, increasing asthma prevalence trends in the 1980s and early 1990s (2). The cause of increasing asthma prevalence has puzzled researchers for

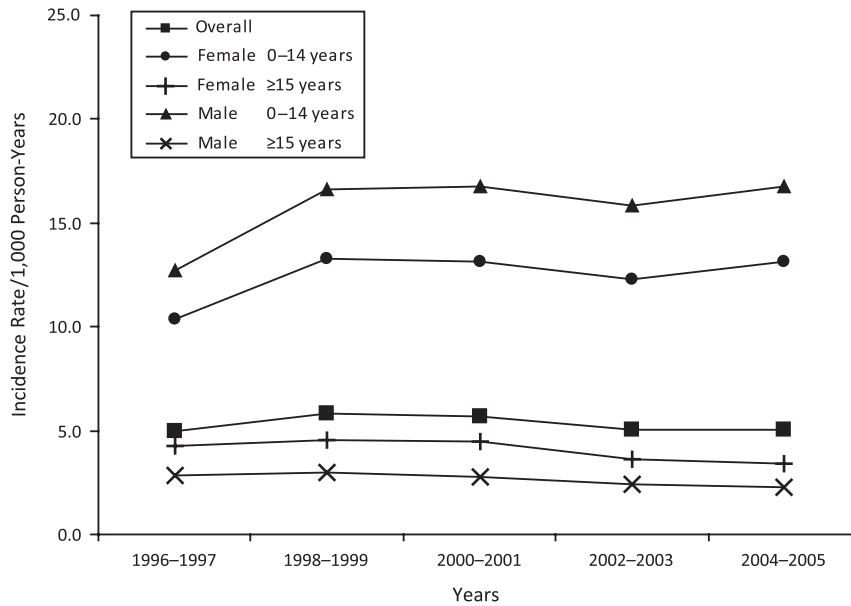


Figure 2. Asthma standardized incidence rates in the province of Ontario, Canada, overall and by sex and age group, from 1996 to 2005.

years and still remains unknown. Proposed contributing factors have included exposure to air pollution, infections, and microbial substances in the environment (2). Allergy is one potential etiologic factor that has become more common in Ontario over the last decade and could have contributed to the increases seen (5). Obesity, more controversially, is another (27).

Although the prevalence of asthma in our study did level off in later years, the overall increasing trend we found differed from results from other studies that demonstrated a stabilization or decrease in asthma prevalence during the same time period. As alluded to above, this might have been because our study focused on the entire population, while other studies examined only specific groups, such as school children. It might also have been because our study measured asthma of a different severity from that of others (26, 28). For example, our study might have captured individuals with milder asthma—whose prevalence was increasing—while other studies measured more severe asthma whose prevalence was decreasing.

Another reason why our study differed from others might have been because it used health administrative data as opposed to survey data to estimate asthma prevalence. Survey data, unlike health administrative data which are collected at the time of diagnosis, are dependent on individuals' memories and subject to recall bias (being more likely to remember recent as opposed to remote events) (8). Such recall bias in other studies might have meant that their "prevalent asthma" was more likely to represent recently diagnosed, as opposed to remotely diagnosed, asthma and, therefore, might have been a closer approximation of the "incident" (rather than the "prevalent") asthma measured in our study, which we also found to be stable/modestly decreasing. Lack of agreement between survey and health administrative data

(which has been described in the literature) is also the reason why we hesitate to make direct, absolute prevalence comparisons between this and other studies (29). For example, our overall asthma prevalence in 2005 (13.3%) was higher than the prevalence found in the 2005 National Health Survey done in the United States of 11.2% (30). We suspect that much of the difference between these values is due to different methods of measurement and not large differences in the populations; however, this would need to be confirmed by further study.

The strengths of our study were its use of large, comprehensive health administrative databases of the entire population to identify individuals with asthma (using a validated case definition) and being able to follow them over time. Its main limitation was its use of physician-diagnosed asthma, which may have been subject to some misclassification bias. Nonetheless, we believe that any such bias would have been consistent over the years studied and be unlikely to affect prevalence trends that were the main outcome of our study. Indeed, others have compared asthma health administrative and survey data and found that, while there were differences in absolute values, health administrative data were consistent over time and therefore reliable for studying asthma trends (29). In order to ensure that misclassification did not play a prominent role in determining asthma trends, we repeated the analysis using a health administrative case definition of asthma with high specificity (but limited sensitivity) and found very similar results.

In summary, we conducted a population study of all individuals in Ontario, Canada, with asthma over 10 years and found asthma prevalence to have increased by over 50% while its incidence remained relatively stable. These data are important to demonstrate the increasing burden and impact of asthma on society and to enable health-care

Table 3. Age- and Sex-specific All-Cause Mortality of Individuals with Asthma in the Province of Ontario, Canada, in 1996, 2001, and 2005

Group	1996			2001			2005			% Change from 1996 to 2005		
	Deaths, no.	Asthma Population, no.	Death Rate/100,000	Deaths, no.	Asthma Population, no.	Death Rate/100,000	Deaths, no.	Asthma Population, no.	Death Rate/100,000	Deaths	Asthma Population	Death Rate
Overall												
≤4 years	52	132,515	39.2	40	117,684	34.0	23	103,627	22.2	-55.8	-21.8	-43.5
5-9 years	17	142,830	11.9	26	188,395	13.8	27	172,770	15.6	58.8	21.0	31.3
10-14 years	19	96,967	19.6	42	174,593	24.1	44	213,331	20.6	131.6	120.0	5.3
15-39 years	234	297,800	76.1	338	446,157	73.3	394	566,123	69.6	68.4	90.1	-8.5
40-69 years	1,993	230,434	790.7	2,635	366,864	703.3	3,073	467,675	657.1	54.2	103.0	-16.9
≥70 years	5,216	74,811	7,568.7	7,400	115,290	6,766.4	8,575	139,051	6,166.8	64.4	85.9	-18.5
All ages ^a	7,462	700,012	887.6	10,415	1,102,904	795.3	12,086	1,386,180	730.0	62.0	98.0	-17.8 ^{*b}
Female												
≤4 years	21	51,394	40.9	17	45,430	37.4	8	39,552	20.2	-61.9	-23.0	-50.5
5-9 years	9	59,231	15.2	8	76,417	10.5	13	69,585	18.7	44.4	17.5	23.0
10-14 years	6	42,024	14.3	15	74,477	20.1	11	88,724	12.4	83.3	111.1	-13.2
15-39 years	104	178,488	54.6	167	252,603	61.1	181	302,237	57.3	74.0	69.3	4.9
40-69 years	959	143,549	639.3	1,393	229,902	601.5	1,655	292,160	566.3	72.6	103.5	-11.4
≥70 years	2,700	45,083	6,393.4	4,115	71,065	5,954.2	4,783	86,556	5,347.0	77.1	92.0	-16.4
All ages ^a	3,799	519,769	739.1	5,715	749,894	694.0	6,651	878,814	630.8	75.1	69.1	-14.7 ^c
Male												
≤4 years	31	81,121	38.2	23	72,254	31.8	15	64,075	23.4	-51.6	-21.0	-38.7
5-9 years	8	83,599	9.6	18	111,978	16.1	14	103,185	13.6	75.0	23.4	41.8
10-14 years	13	54,943	23.7	27	100,116	27.0	33	124,607	26.5	153.8	126.8	11.9
15-39 years	130	119,312	103.4	171	193,554	88.0	213	263,886	85.9	63.8	121.2	-16.9
40-69 years	1,034	86,885	1,042.2	1,242	136,962	872.4	1,418	175,515	808.2	37.1	102.0	-22.5
≥70 years	2,516	29,728	9,621.0	3,285	44,225	8,179.8	3,792	52,495	7,542.5	50.7	76.6	-21.6
All ages ^a	3,732	455,588	1,139.5	4,766	659,089	966.6	5,485	783,763	893.7	47.0	72.0	-21.6 ^c

* $P < 0.001$ for comparison of rates over time, from 1996 to 2005.

^a Rates are standardized to the 2005 Ontario population.

^b Rates between ages are standardized by gender to the 2005 Ontario population; $P < 0.001$ for comparison of rates between age groups.

^c Rates between sexes are standardized by age to the 2005 Ontario population; $P < 0.001$ for comparison of rates between sexes.

providers and policy makers to plan effective clinical and public health strategies. Future research should focus on identifying individuals who are at higher risk of developing asthma and developing strategies to prevent and manage this common disease.

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APPENDIX

Because asthma can sometimes be in remission for a long time and because we did not have a lifetime of data for all subjects to detect if and when they had been diagnosed with asthma in the past, it was presumed that there were individuals with prevalent asthma, diagnosed prior to our study period, who incorrectly appeared as incident asthma cases in our study. In order to correct for this overcounting of

incident cases and to remove them from our incident cohort, the following steps were taken.

First, the unadjusted age-specific incidence rate of asthma that included all individuals who appeared to have incident asthma (both correctly identified and those who had been “overcounted”) during the study period was estimated:

e = number of incident events at age A ;

r = number of person-years contributed by persons at risk entering age A ;

Unadjusted asthma incidence rate (per 1,000 person-years) = $(e/r) \times 1,000$.

Then, the whole asthma cohort was used to estimate the cumulative proportion of individuals at each age who had been diagnosed with asthma in the past and who had potentially been overcounted in our study (24):

p_A = cumulative risk of developing asthma from birth until age A .

Then, the proportion of individuals who had been diagnosed with asthma prior to a given age (potential overcounted cases) was removed from the unadjusted age-specific incidence rate to create an adjusted asthma incident rate.

Adjusted asthma incidence rate/1,000 person-years = $[e \times (1 - p_A)]/[r - e \times p_A] \times 1,000$.

Finally, the age-specific incidence rates were aggregated into groups to produce the results presented (24).