Asthma Deaths in a Large Provincial Health System

A 10-Year Population-Based Study

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Abstract

Rationale: Individuals with asthma are more likely to die from chronic conditions than the general population. Measuring only mortality with asthma listed as the primary cause of death may lead to an underestimation of total asthma mortality.

Objectives: To examine mortality patterns in the asthma population over 10 years, including asthma as the primary cause of death (asthma-specific mortality) and asthma as a secondary, contributing cause of death (asthma-contributing mortality).

Methods: Health administrative data from Ontario, Canada were used to identify mortality rates and cause of death in subjects 0 to 99 years of age. Mortality rates were calculated in the asthma and general population from 1999 to 2008. Total asthma mortality was estimated by adding rates of asthma-specific and asthma-contributing mortality for years 2003 to 2008.

Measurements and Main Results: Asthma-specific mortality rates per 100,000 asthma population decreased by 54.4% from 13.6 in 1999 to 6.2 in 2008. In 2008, the asthma population had higher all-cause mortality compared with the general population (rate ratio, 1.3), asthma-specific mortality rates were 60% higher among those in the lowest compared with highest socioeconomic status, and total asthma mortality was fourfold higher than asthma-specific mortality alone (21.6 vs. 5.4 per 100,000).

Conclusions: All-cause mortality rates have decreased substantially over the past decade. Compared with the general population, the asthma population has higher all-cause mortality and is more likely to die from comorbid conditions. Total asthma mortality was fourfold higher than asthma-specific mortality, highlighting the importance of comprehensive measurement approaches that include asthma-specific and asthma-contributing mortality.

Keywords: asthma; mortality; cause of death; contributing cause of death

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Asthma is a common chronic condition affecting 300 million children and adults worldwide and resulting in roughly 250,000 deaths each year (1, 2). Asthma mortality has been gradually declining since the late 1990s (3, 4), likely due to advances in asthma management, particularly the increased use of inhaled corticosteroids (4). Although the declining rate of asthma-specific mortality is encouraging, it should not invite complacency for treatment of a disease in which the majority of deaths are preventable (5, 6).

A recent report of asthma deaths in the United Kingdom described that over half of

the individuals who died from asthma were being treated for mild or moderate asthma and that neither the patients nor their doctors realized the true asthma severity (7). To complicate matters, individuals with asthma are more likely to have other chronic conditions (e.g., cardiovascular disease, diabetes, and psychiatric conditions) than the general population (8–12). McCoy and colleagues (13) examined specific and contributing causes of death in the United States population using data compiled by the National Center for Health Statistics from 1990 to 2001. They showed that when considered not only as a sole cause of death but also as a contributing cause of death, asthma accounted for over twice as many deaths. Thus, examining only asthma as the specific cause of death (asthma-specific mortality) may result in an underestimation of total deaths attributable to asthma. To fully understand the extent of asthma mortality, consideration must be taken for both asthma-specific mortality and asthma as a contributing cause of death (asthma-contributing mortality).

Having an accurate assessment of total asthma mortality will better enable researchers, physicians, and policy makers to monitor improvements in asthma control over time. Furthermore, better knowledge of asthma-contributing mortality will bring awareness to the importance of treating comorbidities along with asthma within the asthma population.

We conducted the current study to examine mortality trends in the asthma population in Ontario, Canada compared with the general population and to estimate total asthma mortality using asthma-specific and asthma-contributing mortality.

Methods

Data Source

Population-based data from Ontario, a province in Canada with 13 million residents, were used for this study. Ontario has a universal, single-payer health-care system that covers all physician and hospital services. Data were available from four health administrative databases: (*1*) The Ontario Health Insurance Plan Database contains information on all fee-for-service billings for physician services rendered and for emergency department visits in Ontario, including diagnosis; (*2*) The Canadian Institute for Health Information Discharge Abstract Database records the primary diagnosis and up to 15 secondary diagnoses for all patients discharged from acute care hospitals before 2002 and up to 25 secondary diagnoses in 2002 and later years; (*3*) The Ontario Registered Persons Database includes information on sex, birth date, and residence postal code; and (*4*) The Vital Statistics Database contains specific and contributing causes of death and date of death. These databases were linked on an individual level using an encrypted unique health card number given to all Ontario residents. This linkage allows for protection of the identities of individuals while examining their health services use across health administrative databases. These databases are housed at the Institute for Clinical Evaluative Sciences in Ontario, Canada.

Asthma Case Definition

The Ontario Asthma Surveillance Information System (OASIS) uses these databases to create a population-based longitudinal surveillance system that identifies and tracks individuals living with asthma (14). Individuals with asthma were identified as those who, from 1991 to 2009, had at least two asthma outpatient claims in two consecutive years or one hospitalization for asthma. This asthma health administrative data case definition was previously shown to have 89% sensitivity and 72% specificity in children (i.e., patients under 18 yr of age) and 83.8% sensitivity and 76.5% specificity in adults aged 18 years or over, with a low overall false-negative rate of less than 2% and a false-positive rate of 13.3% compared with a clinical reference standard (14, 15). All individuals 0 to 99 of age with asthma included in OASIS from April 1, 1999 to March 31, 2009 were included in this study as the asthma prevalent population (hereafter referred to as the "asthma population").

Outcome Measures

All deaths in the Ontario population during the study interval were extracted from the vital statistics database, which describes cause of death according to International Classification of Diseases (ICD-9) codes. Cases with asthma listed as the primary cause of death (asthma-specific mortality) or as one of the secondary causes of death (asthma-contributing mortality) were extracted from the vital statistics database. Asthma-related conditions include acute respiratory infections, other diseases of the upper respiratory tract, other diseases of the lung or respiratory system, atopic dermatitis and related conditions, and symptoms involving respiratory system and other chest symptoms; in adults, asthma-related conditions also include gastro-esophageal reflux disorder, heartburn, and allergic contact dermatitis. The "other respiratory diseases" are those that were coded as diseases of the respiratory system in the vital statistics database but were not asthma, asthma-related, COPD/emphysema/bronchitis, influenza, or pneumonia. Mortality data were available from April 1, 2003 to March 31, 2008. ICD-9 codes for each main cause of death to which asthma contributed are detailed in an online supplement.

Covariates Analyzed as Contributing Factors in Total Asthma Mortality

Individual-level factors: All analyses were stratified by and adjusted for age and sex. The place of residence at time of death was classified as rural (communities with population of $<$ 10,000) or urban (communities with population of $\geqslant$ 10,000).

Neighborhood-level factors: A proxy measure of socioeconomic status (SES) was obtained through the Ontario Marginalization Index (ON-Marg) (16). The ON-Marg is a census- and geographically based index that uses multiple dimensions to show differences in marginalization between geographic areas. In the current analyses, the material deprivation dimension (which includes measures on high school graduation, single-parent families, government transfers, unemployment, low income, and homes needing major repairs) was used as a proxy measure of SES and was expressed in quintiles, with Q1 being the least deprived population (i.e., highest SES) and Q5 being the most deprived population (i.e., lowest SES).

Statistical Analysis

Descriptive annual mortality rates were calculated per 100,000 individuals in the asthma and general population from 1999 to 2008. Crude mortality rates were stratified by age and sex, deprivation quintile, and rural or urban residence. Age- and sex-adjusted, cause-specific mortality rates were calculated using the Ontario Census

Population of 2006 as the standard population (the closest available census year between 2003 and 2008 of the study period), and γ-based 95% confidence intervals (CIs) were determined. Statistical significance in trends was measured using the Cochrane-Armitage Test for Trend (17).

Total asthma mortality was the sum of asthma-specific mortality and asthma-contributing mortality. The ratio of total asthma mortality to asthma-specific mortality was calculated by dividing the former by the latter.

We used the Poisson regression to model the rate ratios of asthma-specific mortality and asthma-contributing mortality while adjusting for age, sex, rural/urban residence, and deprivation quintiles. The 2006 asthma population was used as the offset or denominator for the rates in the regression models. The deviance and Pearson χ^2 divided by the degrees of freedom were used to measure dispersion. All analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary, NC).

Results

Trends in All-Cause Mortality Rates in Asthma and General Population

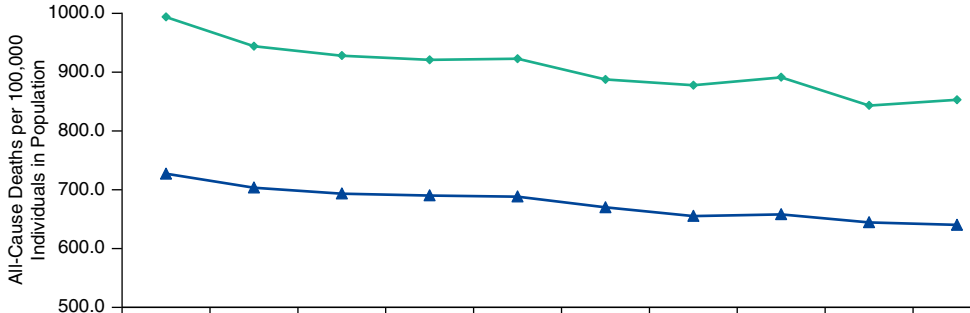
Although both the asthma (−16.5%) and general (−13.6%) populations showed a decline in overall age- and sex-adjusted all-cause mortality rates per 100,000 people over a 10-year interval between 1999 and 2008, the all-cause mortality rate remained consistently higher in the asthma population compared with the general population (Figure 1). Table 1 shows the distribution of all-cause mortality rates in the asthma population from 1999 to 2008 by demographic characteristics. Overall, all-cause mortality rates decreased over time among men (788.0–677.5 per 100,000; $P < 0.0001$), those 40 years of age and older, and those in the lowest deprivation quintiles (i.e., highest SES) but did not show a statistically significant decrease among those 0 to 39 years of age or those in the higher deprivation quintiles (quintiles 3 to 5). Although the data in Table 1 did not show a significant decline in all-cause mortality in women overall, there was a decline in women 60 years of age and over. Asthma prevalence rates increased over the same period (*see* Table E1 in the online supplement).

Cause-specific Mortality Rates in the Asthma and General Populations

Age- and sex-adjusted cause-specific mortality rates were compared between the asthma and general populations in 1999 and 2008 (Table 2). The asthma population showed a slightly larger decrease in age- and sex-adjusted all-cause mortality rates from 1999 to 2008 compared with the general population. The asthma population continued to have significantly higher all-cause mortality overall compared with the general population in 2008 (mortality rate ratio [MRR], 1.3) (Table 2). Although the mortality rate from diseases of the respiratory system in the asthma population was almost three times higher than the general population, there was a 25% decrease over time (from 194.3 to 145.0 per 100,000) (Table 2). Asthma-specific mortality rates per 100,000 asthma population decreased from 13.6 in 1999 to 6.2 in 2008 (54.4% decrease) (Table 2). Figure 2 is a forest plot that shows the MRRs comparing each cause of death between the asthma and general population in 2008. Compared with the general population, the asthma population had higher MRRs for nearly all specific causes of death, with the highest rate ratios for diseases of the respiratory system as a whole (MRR, 2.75; 95% CI, 2.68–2.83) and COPD in particular (MRR, 3.70; 95% CI, 3.55–3.85), indicating a substantial comorbidity of COPD in the asthma population. Figure 3 illustrates age- and sex-adjusted death rates from diseases of the respiratory system per 100,000 asthma population from 1999 to 2008. Over time, there was a general decreasing trend in mortality from COPD, influenza, and pneumonia, whereas there was a small increase in mortality from asthma-related conditions and other respiratory diseases.

Total Asthma Mortality

To describe the total burden of asthma mortality, we calculated the ratio of total asthma mortality to asthma-specific mortality per 100,000 asthma population (Table 3). Total asthma mortality includes asthma-specific and asthma-contributing



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Percent Change 1999-2008
◆ Asthma Population	992.6	943.1	927.0	920.0	921.9	886.7	876.8	890.3	842.5	852.1	16.5%
▲ General Population	726.8	703.2	693.0	689.8	687.9	669.6	655.0	657.9	644.2	639.9	13.6%
Percent Difference	36.6%	34.1%	33.8%	33.4%	34.0%	32.4%	33.9%	35.3%	30.8%	33.2%	

Figure 1. Age- and sex-adjusted all-cause mortality rate per 100,000 asthma population and general population, fiscal years 1999 to 2008.

Table 1. Unadjusted all-cause mortality rates in the asthma population, 1999–2008*

Demographics	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	*P* Value†
Sex and age group (yr)											
Both sexes	776.3	745.3	744.1	739.4	749.5	728.6	724.3	742.0	708.3	725.8	<0.0001
0–19	22.4	20.4	23.0	19.2	19.9	20.5	21.5	21.2	19.8	21.5	0.7349
20–39	75.1	78.8	84.6	77.3	69.3	72.4	78.4	74.4	69.4	73.1	0.1161
40–59	429.4	379.8	383.3	426.2	397.8	356.9	362.5	379.9	375.6	366.1	<0.0001
60–79	3,035.4	2,937.0	2,890.5	2,691.6	2,778.2	2,581.4	2,510.3	2,433.5	2,241.1	2,199.2	<0.0001
80–99	13,687.6	12,988.4	12,360.6	12,339.5	12,037.2	11,845.0	11,403.7	11,736.9	11,042.2	11,248.4	<0.0001
Female	766.1	739.4	765.8	754.3	767.0	754.6	752.3	778.2	750.7	769.4	0.3589
0–19	20.4	17.0	20.2	14.7	14.7	16.6	19.1	15.4	17.8	16.1	0.3951
20–39	61.4	61.0	76.5	67.2	56.1	54.8	64.1	58.1	50.8	63.7	0.1145
40–59	347.1	326.9	337.8	356.7	334.6	307.2	319.0	330.6	333.4	320.6	0.1326
60–79	2,489.5	2,394.5	2,430.3	2221.7	2,332.0	2,134.2	2,089.6	2,061.1	1,917.7	1,874.7	<0.0001
80–99	12,078.6	11,410.6	11,196.8	11171.9	10,782.7	10,841.4	10,301.4	10,637.5	10,014.6	10,147.2	<0.0001
Male	788.0	752.2	719.4	722.6	729.7	699.3	692.9	701.6	661.0	677.5	<0.0001
0–19	23.9	22.9	25.0	22.4	23.6	23.3	23.2	25.4	21.2	25.4	0.8843
20–39	96.7	106.4	96.8	92.4	88.3	97.3	97.9	95.9	93.2	84.6	0.1900
40–59	572.7	471.5	461.6	545.2	505.3	440.9	435.3	461.7	445.2	440.5	<0.0001
60–79	3,849.8	3,756.3	3,590.5	3413.5	3,471.1	3,281.1	3,174.6	3,026.3	2,760.8	2,726.0	<0.0001
80–99	16,707.3	16,012.5	14,607.2	14578.8	14,442.5	13,781.7	13,518.8	13,842.4	13,018.8	13,366.6	<0.0001
Deprivation quintile											
1 (least deprived)	732.9	704.8	696.3	719.0	681.0	660.1	658.7	665.9	642.3	626.8	<0.0001
2	710.7	673.2	643.8	654.0	660.4	645.9	648.6	676.4	611.0	645.7	0.0010
3	762.1	725.6	739.8	713.0	762.5	726.5	725.9	718.5	711.6	751.6	0.3527
4	820.8	795.4	807.5	813.1	834.7	841.5	812.9	847.1	801.8	842.3	0.1744
5 (most deprived)	836.9	814.6	812.2	793.6	806.7	785.4	787.6	832.2	809.6	826.2	0.9331
Rural or urban residence‡											
Rural	1,008.5	971.3	940.5	966.9	966.2	958.4	929.1	941.5	874.8	936.7	0.0008
Urban	745.5	715.6	717.9	709.3	720.1	699.7	699.3	717.8	688.1	700.7	<0.0001

*Rate calculated per 100,000 asthma prevalent population.
†*P* value calculated using the Cochran-Armitage Trend Test.
‡Rural community defined as one with fewer than 10,000 residents.

mortality. In 2008, the total asthma mortality rate was 21.6 per 100,000, whereas the asthma-specific mortality rate was 5.4 per 100,000. Their rate ratio of 4.0 (95% CI, 3.2–5.0) suggests that for each individual who was found to have died with asthma as the specific cause of death, there were four individuals who died with asthma as a contributing cause. The rate ratios ranged from 3.4 (95% CI, 2.8–4.2 in 2003) to 4.8 (95% CI, 3.7–6.2 in 2007).

Factors Associated with Total Asthma Mortality

Adjusted Poisson regression analysis for all-cause mortality, asthma-specific mortality, and asthma-contributing mortality (Table 4) showed that, as expected, all-cause mortality, asthma-specific mortality, and asthma-contributing mortality increased with age. No significant differences were found between asthma-specific mortality rates of those living in rural areas compared with urban areas. Those with asthma from deprivation quintile Q5 (most deprived) had a 60% higher rate of asthma-specific mortality (relative risk [RR], 1.60; 95% CI, 1.16–2.20) and a 34% higher rate of asthma-contributing mortality (RR, 1.34; 95% CI, 1.10–1.64) than those from deprivation quintile Q1 (least deprived). A sensitivity analysis was conducted by repeating the Poisson regression analysis while excluding individuals under 3 years of age, and results demonstrated no significant changes (Table E2).

Discussion

This population-based study found that the all-cause mortality rate in the asthma population in Ontario decreased from 1999 to 2008. However, among the asthma population, all-cause mortality rate in women under 60 years of age, those in the highest deprivation quintile, and those 0 to 39 years of age did not decline. Furthermore, although the gap in mortality rates between the asthma population and general population has narrowed over time, the asthma population continues to have higher all-cause mortality than the general population and has higher cause-specific mortality rates for all major chronic diseases except mental health. Our study was the first that used population-based data from a universal, single-payer health care system to quantify total asthma mortality by examining asthma-contributing mortality in addition to asthma-specific mortality. Our results showed that for each individual who died with asthma as the specific cause, there were four individuals who died with asthma as a contributing cause of death. Traditional methods of measuring asthma mortality would not include these individuals and thus would underestimate total asthma mortality.

Our study reported a similar mortality patterns to that of prior studies (i.e., a decrease in asthma-specific and all-cause mortality rates in the asthma population over time) (3, 4). Decreased asthma-specific mortality rates are often attributed to improved asthma management. Over the past 10 years in Ontario, as part of

Table 2. Age- and sex-adjusted cause-specific mortality rates and mortality rate ratio in the asthma and general populations, 1999 and 2008

Cause of Death	1999			2008		
	Asthma	General	MRR	Asthma	General	MRR
	Rate* (95% CI)	Rate† (95% CI)		Rate* (95% CI)	Rate† (95% CI)	
All causes of death	992.6 (972.5–1,013.0)	726.8 (721.7–731.9)	1.4	852.1 (837.5–867.0)	639.9 (635.6–644.2)	1.3
Diseases of the respiratory system	194.3 (185.6–203.3)	63.0 (61.5–64.5)	3.1	145.0 (139.0–151.2)	52.7 (51.5–53.9)	2.8
Asthma	13.6 (11.3–16.2)	1.2 (1.0–1.5)	11.1	6.2 (5.0–7.6)	0.7 (0.6–0.9)	8.4
COPD/emphysema/bronchitis	126.2 (119.2–133.4)	27.8 (26.8–28.9)	4.5	88.2 (83.6–93.1)	23.9 (23.0–24.7)	3.7
Asthma related	8.3 (6.5–10.3)	2.3 (2.0–2.6)	3.6	11.6 (10.0–13.5)	3.0 (2.7–3.3)	3.8
Other respiratory diseases	16.7 (14.2–19.5)	7.6 (7.1–8.1)	2.2	21.6 (19.3–24.1)	11.1 (10.5–11.6)	2.0
Influenza	3.1 (2.2–4.4)	2.6 (2.3–2.9)	1.2	1.0 (0.6–1.6)	0.7 (0.5–0.8)	1.5
Pneumonia	26.5 (23.4–29.9)	21.5 (20.6–22.4)	1.2	16.3 (14.3–18.5)	13.3 (12.7–14.0)	1.2
Congenital anomalies	2.2 (1.4–3.3)	1.4 (1.2–1.6)	1.6	1.9 (1.3–2.7)	1.1 (1.0–1.3)	1.6
Infectious and parasitic diseases	18.0 (15.3–21.1)	10.8 (10.2–11.5)	1.7	22.0 (19.7–24.5)	14.8 (14.2–15.5)	1.5
Diseases of the musculoskeletal system and connective tissue	5.0 (3.7–6.6)	3.9 (3.5–4.3)	1.3	7.0 (5.7–8.4)	4.0 (3.7–4.4)	1.7
Diseases of the genitourinary system	19.2 (16.5–22.1)	13.6 (12.9–14.3)	1.4	18.6 (16.6–20.9)	13.9 (13.3–14.6)	1.3
Diseases of the digestive system	35.2 (31.4–39.3)	27.4 (26.5–28.4)	1.3	36.1 (33.2–39.3)	27.2 (26.4–28.1)	1.3
Endocrine, nutritional, and metabolic diseases and immunity disorders	33.5 (29.9–37.4)	29.1 (28.1–30.1)	1.2	38.0 (35.0–41.3)	28.9 (28.0–29.9)	1.3
Diseases of the blood and blood-forming organs	3.0 (2.0–4.4)	2.5 (2.2–2.8)	1.2	1.4 (0.9–2.1)	1.7 (1.5–2.0)	0.8
Diseases of the skin and subcutaneous tissue	1.7 (1.0–2.8)	1.1 (0.9–1.3)	1.6	2.1 (1.4–3.0)	1.1 (0.9–1.3)	1.9
Diseases of the circulatory system	328.9 (317.5–340.6)	267.8 (264.7–270.9)	1.2	239.9 (232.1–247.8)	189.5 (187.1–191.8)	1.3
External causes of injury and poisoning	45.4 (40.9–50.2)	38.2 (37.0–39.4)	1.2	52.7 (49.0– 56.6)	39.5 (38.4–40.6)	1.3
Neoplasms	266.3 (255.9–277.0)	216.2 (213.4–219.0)	1.2	222.8 (215.3–230.5)	195.8 (193.5–198.2)	1.1
Conditions	5.9 (4.4–7.7)	6.8 (6.3–7.3)	0.9	5.4 (4.2–6.7)	4.7 (4.3–5.1)	1.1
Mental disorders	12.4 (10.3–14.8)	20.1 (19.2–20.9)	0.6	30.7 (28.1–33.6)	33.2 (32.3–34.2)	0.9
Diseases of the nervous system and sense organs	21.5 (18.7–24.7)	25.0 (24.1–26.0)	0.9	28.3 (25.8–31.1)	31.6 (30.6–32.5)	0.9
Certain conditions originating in the perinatal period	0.1 (0.0–0.4)	0.1 (0.0–0.1)	2.6	0.2 (0.1–0.4)	0.1 (0.0–0.1)	2.4
Complications of pregnancy, childbirth, and the puerperium	0.1 (0.0–0.4)	0.1 (0.0–0.1)	1.6	0.0 (0.0–0.0)	0.0 (0.0–0.1)	0.0
Other diseases	0.0 (0.0–0.0)	0.1 (0.0–0.1)	0.0	0.1 (0.0–0.3)	0.0 (0.0–0.1)	2.0

Definition of abbreviations: CI = confidence interval; COPD = chronic obstructive pulmonary disease; MRR = mortality rate ratio.
*Rate calculated per 100,000 asthma population.
†Rate calculated per 100,000 general population.

a provincial asthma strategy many resources have been put toward initiatives aimed at improving quality of asthma care and asthma management. For example, a Primary Care Asthma Program (Ontario Lung Association) has been implemented in over 160 primary care locations (18), and standardized Emergency Department Asthma Care Pathways (Ontario Lung Association) have been implemented (19) with the aim of providing tools to guide practitioners and patients to more effectively manage asthma. However, despite a narrowing in the gap between the asthma and the general population for asthma- and all-cause mortality, the gap remains large. We demonstrated that individuals with asthma are more likely than the general population to die of other chronic conditions. Focusing clinically on improving the quality of care of other chronic conditions and further research into the health impact of comorbidities on the asthma population may improve outcomes and narrow this gap.

Although the all-cause mortality rate has decreased over time, our Poisson regression analysis showed that asthma-specific mortality rates were higher among the older age groups and those with lower SES. Furthermore, the asthma-specific mortality rates among these groups did not decline over time. These findings identify an important area of exploration for future research to explain the disparity and to identify asthma subpopulations that can be targeted with programs to reduce total asthma mortality. This finding was also observed among individuals 0 to 39 years of age. We speculate the reason that mortality rates among individuals 0 to 39 years of age did not decline is that they were low at baseline, and thus there was limited room for them to decline.

Similar to the general population, the top three causes of death in the asthma population apart from diseases of the respiratory system were (*1*) cancer, (*2*) diseases of the circulatory system, and (*3*) endocrine, nutritional, and metabolic diseases and immunity disorders. The

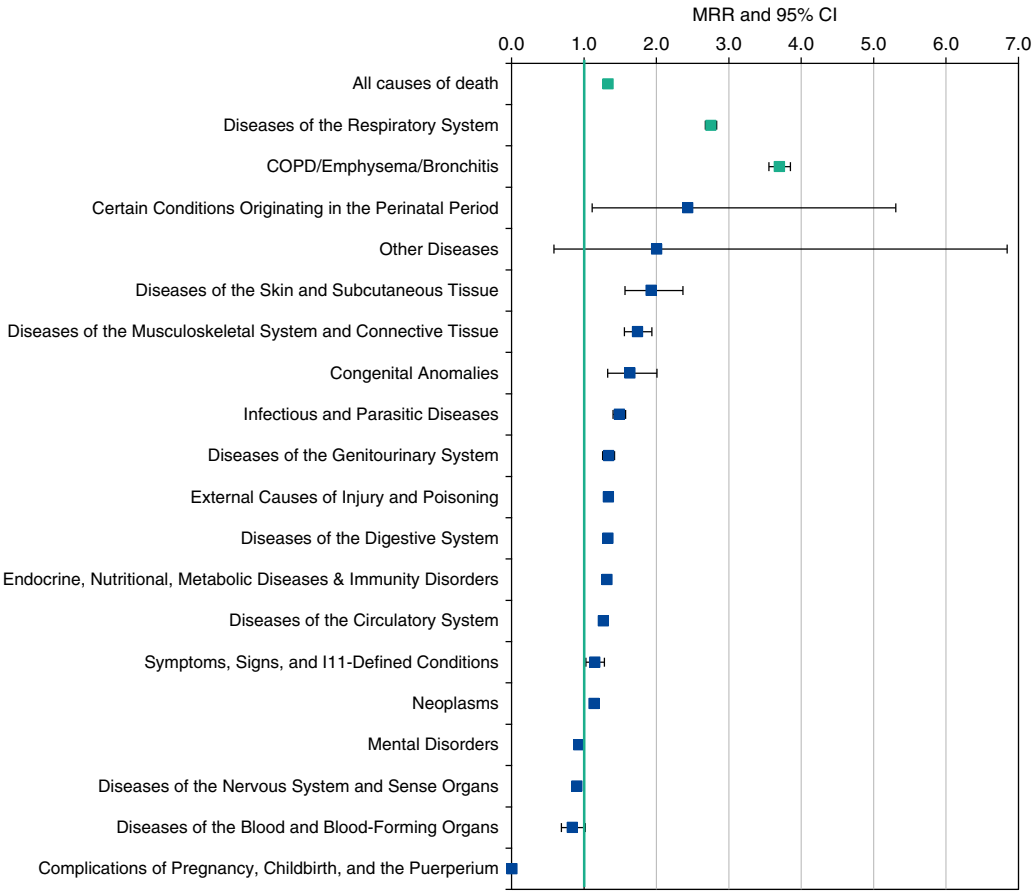


Figure 2. Mortality rate ratios (MRR) by specific causes of death between the asthma and general populations, 2008. CI = confidence interval; COPD = chronic obstructive pulmonary disease.

asthma population had a higher risk of mortality than the general population for these conditions and for the majority of the other chronic conditions examined. These findings are not surprising: Gershon and colleagues found that individuals with asthma had a much higher rate of comorbidity than individuals without asthma (9).

When including asthma as a contributing cause of death in our total asthma mortality calculation, we found the rate of total asthma mortality to be roughly 4-fold higher than that captured when only examining asthma as the specific cause of death. This rate is 2 times higher than found by McCoy and colleagues (13). This suggests that previous estimates of asthma mortality based solely on asthma as a specific cause of death may be underestimated. This finding, in combination with the finding that the asthma population are more likely to have and die from other chronic conditions, stresses the importance of taking a comprehensive approach when measuring and evaluating changes in total asthma mortality over time.

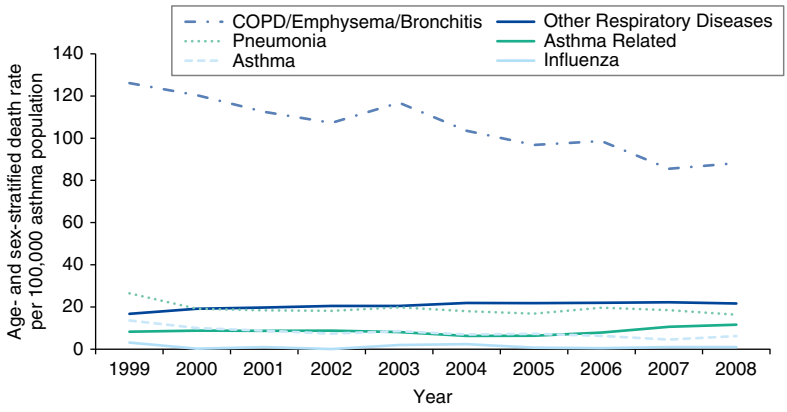


Figure 3. Age- and sex-adjusted mortality rates from diseases of the respiratory system per 100,000 asthma population, fiscal years 1999 to 2008. COPD = chronic obstructive pulmonary disease.

This longitudinal population-based study had a number of strengths, including a large sample size, complete information on patient demographics, and accounting for all deaths in the population. However, a few limitations should be noted. The health administrative data definition of asthma may be subject to potential misclassification when compared with clinical evaluation by a physician, compounded by the fact that physicians do not always accurately diagnose asthma. Asthma has been shown to

Table 3. Asthma-specific and asthma-contributing mortality in asthma population, 2003–2008

Burden of Asthma Mortality	2003		2004		2005		2006		2007		2008	
	Number	Rate*	Number	Rate*	Number	Rate*	Number	Rate*	Number	Rate*	Number	Rate*
Asthma-underlying mortality	109	7.1	90	5.6	102	6.1	93	5.4	71	4.0	99	5.4
Asthma-contributing mortality	264	17.1	289	18.0	307	18.4	282	16.3	267	15.0	297	16.2
Total asthma mortality (asthma-underlying + asthma-contributing mortality)	373	24.2	379	23.6	409	24.5	375	21.6	338	19.0	396	21.6
Rate ratio of total asthma mortality to asthma-underlying mortality		3.4		4.2		4.0		4.0		4.8		4.0
95% confidence intervals of rate ratio		2.8–4.2		3.4–5.3		3.2–5.0		3.2–5.1		3.7–6.2		3.2–5.0

*Rates calculated per 100,000 asthma population.

be both overdiagnosed and underdiagnosed by physicians; thus, it is not clear how such possible misdiagnosis influenced our results (20–22). That being said, the asthma case definition we used in this study has been previously validated with chart abstraction studies (14, 15). Also, physicians and coroners may differ in what they record as the primary versus secondary causes of death. It is possible that some of the observed decrease in asthma mortality may be explained by a potential coding shift between the different respiratory diseases; specifically, whereas there was a general decreasing trend for COPD, influenza, and pneumonia, there was a small increase in mortality due to asthma-related conditions and other respiratory diseases.

A potential explanation for the decline in all-cause mortality over time may be the increase in asthma prevalence. If the increase in asthma prevalence is due to higher rates of diagnoses of milder asthma, the denominator of the mortality rate equation would be larger, resulting in a lower mortality rate. The mortality data do not provide information on how much asthma

Table 4. Adjusted Poisson regression model for asthma-underlying and asthma-contributing mortality

Risk Factors	All-Cause Mortality	Asthma-Underlying Mortality	Asthma-Contributing Mortality
Sex			
Male (reference)	1.00*	1.00	1.00
Female	0.72 (0.68–0.76)	1.12 (0.91–1.39)	1.09 (0.95–1.23)
Age groups, yr			
1–39 (reference)	1.00	1.00	1.00
40–59	9.49 (8.09–11.13)	3.60 (2.47–5.24)	8.21 (5.89–11.44)
60–79	62.90 (54.41–72.72)	11.20 (7.96–15.76)	39.10 (28.82–53.04)
⩾80	292.89 (253.52–338.39)	70.59 (51.20–97.30)	210.65 (156.01–284.44)
Residence			
Urban (reference)	1.00	1.00	1.00
Rural	1.16 (1.08–1.25)	0.91 (0.66–1.27)	1.03 (0.85–1.25)
Deprivation quintile			
1 (least deprived)	1.00	1.00	1.00
2	1.05 (0.96–1.14)	1.03 (0.74–1.44)	1.07 (0.88–1.30)
3	1.12 (1.03–1.21)	1.15 (0.83–1.59)	1.07 (0.88–1.30)
4	1.20 (1.10–1.30)	1.37 (0.99–1.89)	1.17 (0.95–1.42)
5 (most deprived)	1.39 (1.28–1.52)	1.60 (1.16–2.20)	1.34 (1.10–1.64)

*Values are rate ratios from adjusted Poisson regression models with 95% confidence intervals in parentheses.

contributed to mortality or on the order in which contributing causes of death were listed on the death certificate; it only informs us that asthma was listed as one of potentially many contributing factors. Furthermore, it has been suggested that death certification data are less accurate in older age groups, which may be attributed to the failure of certifying doctors and coroners to follow appropriate procedures for identification of the primary condition leading to death or misdiagnosis of asthma as other lung diseases (23, 24). Lastly, smoking status was not accounted for when interpreting the data. Individuals with asthma who smoke may be more susceptible to other chronic conditions, such as cancer, cardiovascular disease, and diabetes. If that was the case, smoking among the asthma population may be partially responsible for the higher mortality among individuals with asthma for these diseases.

Future research should examine (*1*) why the all-cause mortality rate among individuals with asthma in the highest deprivation quintile and indicviduals 0 to 39 years of age has remained the same over time and (*2*) the extent of asthma contribution to deaths that had other chronic diseases listed as the main cause. This research could help inform policy makers when allocating resources aimed at improving asthma outcomes.

Conclusions

All-cause mortality rates have decreased substantially over the past decade, excepting the subpopulations of women younger than 60 years of age and individuals of low SES. The asthma population continues to have higher all-cause mortality, and individuals with asthma are more likely to die from comorbid conditions compared with the general population. Individuals of low SES have higher total asthma mortality and all-cause mortality. Total asthma mortality was 4-fold higher than asthma-specific mortality, highlighting the importance of a comprehensive methodological approach that analyzes subpopulations and includes both asthma-specific and asthma-contributing mortality. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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