



Trends and risk factors of mortality and disability adjusted life years for chronic respiratory diseases from 1990 to 2017: systematic analysis for the Global Burden of Disease Study 2017

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ABSTRACT

OBJECTIVE

To describe the temporal and spatial trends of mortality and disability adjusted life years (DALYs) due to chronic respiratory diseases, by age and sex, across the world during 1990-2017 using data from the Global Burden of Disease Study 2017.

DESIGN

Systematic analysis.

DATA SOURCE

The Global Burden of Diseases, Injuries, and Risk Factors Study 2017.

METHODS

Mortality and DALYs from chronic respiratory diseases were estimated from the Global Burden of Disease Study 2017 using DisMod-MR 2.1, a Bayesian meta-regression tool. The estimated annual percentage change of the age standardised mortality rate was calculated using a generalised linear model with a Gaussian distribution. Mortality and DALYs were stratified according to the Socio-demographic index. The strength and direction of the association between the Socio-demographic index and mortality rate were measured using the Spearman rank order correlation. Risk factors for chronic respiratory diseases were analysed from exposure data.

RESULTS

Between 1990 and 2017, the total number of deaths due to chronic respiratory diseases increased by 18.0%, from 3.32 (95% uncertainty interval 3.01 to 3.43) million in 1990 to 3.91 (3.79 to 4.04) million in 2017. The age standardised mortality rate of chronic respiratory diseases decreased by an average of 2.41% (2.28% to 2.55%) annually. During

the 27 years, the annual decline in mortality rates of chronic obstructive pulmonary disease (COPD; 2.36%, uncertainty interval 2.21% to 2.50%) and pneumoconiosis (2.56%, 2.44% to 2.68%) has been slow, whereas the mortality rate for interstitial lung disease and pulmonary sarcoidosis (0.97%, 0.92% to 1.03%) has increased. Reductions in DALYs for asthma and pneumoconiosis have been seen, but DALYs due to COPD, and interstitial lung disease and pulmonary sarcoidosis have increased. Mortality and the annual change in mortality rate due to chronic respiratory diseases varied considerably across 195 countries. Assessment of the factors responsible for regional variations in mortality and DALYs and the unequal distribution of improvements during the 27 years showed negative correlations between the Socio-demographic index and the mortality rates of COPD, pneumoconiosis, and asthma. Regions with a low Socio-demographic index had the highest mortality and DALYs. Smoking remained the major risk factor for mortality due to COPD and asthma. Pollution from particulate matter was the major contributor to deaths from COPD in regions with a low Socio-demographic index. Since 2013, a high body mass index has become the principal risk factor for asthma.

CONCLUSIONS

Regions with a low Socio-demographic index had the greatest burden of disease. The estimated contribution of risk factors (such as smoking, environmental pollution, and a high body mass index) to mortality and DALYs supports the need for urgent efforts to reduce exposure to them.

Introduction

Chronic respiratory diseases pose a major public health problem, with an estimated 3.91 million deaths in 2017, accounting for 7% of all deaths worldwide. Chronic obstructive pulmonary disease (COPD) and asthma are the most common types of chronic respiratory disease. Pneumoconiosis, and interstitial lung disease and pulmonary sarcoidosis are also global public health concerns. These four types of chronic respiratory disease are associated with demographic trends, socioeconomic development, and risk exposures, including smoking, environmental and occupational pollution, and metabolic risks. Over the past three decades, the ageing population has increased rapidly.¹ The prevalence of smoking has declined by 28.4% in males (men and boys) and 34.4% in females (women and girls), respectively, with considerable geographical heterogeneity.² Moreover, sociodemographic development, economic shifts, and risk exposures have changed remarkably over

WHAT IS ALREADY KNOWN ON THIS TOPIC

Chronic respiratory diseases impose a substantial burden on individuals
Previous analyses of mortality and loss of health due to chronic respiratory diseases were based on limited data or confined to local areas

WHAT THIS STUDY ADDS

From 1990 to 2017, increasing trends for deaths and health loss due to chronic respiratory diseases were seen, while the age standardised mortality rate and age standardised disability adjusted life years (DALYs) from chronic respiratory diseases decreased

The global trends of mortality and DALY rates for chronic respiratory diseases varied by age, sex, region, and disease pattern

Negative correlations between the Socio-demographic index and mortality rates of chronic obstructive pulmonary disease, pneumoconiosis, and asthma were seen; regions with a low Socio-demographic index had the greatest disease burden

the decades.^{2,3} As a result, the prevalence of chronic respiratory diseases has changed substantially.

Previous analyses of mortality and loss of health due to chronic respiratory diseases were based on limited data or confined to local areas.^{4,5} In this study, we report the temporal and geographical trends of mortality and disability adjusted life years (DALYs) due to chronic respiratory diseases, by age and sex, across the world during 1990-2017 using data from the Global Burden of Diseases, Injuries, and Risk Factors Study 2017. Risk factors for chronic respiratory diseases, including the Socio-demographic index and various risk exposures, were examined to help policy makers and services reduce mortality due to chronic respiratory diseases, and improve health.

Method

Data source

Data on mortality, DALYs, age standardised mortality rates, and age standardised DALY rates of chronic respiratory diseases in 195 countries and territories during 1990-2017 were obtained from the Global Burden of Disease Study 2017 (publicly available online). Instances of chronic respiratory diseases—COPD, pneumoconiosis (including asbestosis, coal workers' pneumoconiosis, silicosis, and other types of pneumoconiosis), asthma, and interstitial lung disease and pulmonary sarcoidosis—were identified based on the International Classification of Diseases and Injuries-10 diagnostic codes (supplementary table 1).

Covariates included the Socio-demographic index and risk exposures. The Socio-demographic index is a composite indicator of income per capita, average educational attainment, and total fertility rates.⁶ Index values range from 0 (lowest income, fewest years of schooling, and highest fertility) to 1 (highest income, most years of schooling, and lowest fertility). The methods used to calculate the index are provided in the supplementary material.⁷ Countries and territories were classified as regions with a high, high middle, middle, low middle, or low Socio-demographic index. The cut-off values used to determine quintiles for analysis were computed using country level estimates of the Socio-demographic index for the year 2017, excluding countries with populations less than one million.⁷

Risk exposures were defined in the comparative risk assessment framework of the Global Burden of Disease Study 2017, which includes environmental and occupational risks (particulate matter pollution, ambient ozone pollution), behavioural risks (tobacco, including smoking and secondhand smoke), and metabolic risks (high body mass index). The risk factor hierarchy and accompanying definitions of exposure were clarified in the previous study.⁸

Statistical analyses

The standardised methods of the Global Burden of Disease Study 2017 have been extensively reported.⁹

¹⁰ Mortality and DALYs from chronic respiratory

diseases—COPD, pneumoconiosis, asthma, and interstitial lung disease and pulmonary sarcoidosis—were estimated for 195 countries and territories, by age and sex, from 1990 to 2017 using DisMod-MR 2.1, a Bayesian meta-regression tool. We generated 95% uncertainty intervals for all reported data. All estimates were generated from the mean of 1000 draws, and 95% uncertainty intervals were determined using the 2.5th and 97.5th centiles of the ordered draws. According to the previous study,¹¹⁻¹³ the estimated annual percentage change is a summary and widely used measure of the age standardised rate trend over a specified interval. The estimated annual percentage change of the age standardised mortality rate was calculated using a generalised linear model with a Gaussian distribution.¹¹⁻¹⁴

Spearman's rank order correlation was used to measure the strength and direction of the association between the Socio-demographic index and age standardised mortality rate, the change in the Socio-demographic index between 1990 and 2017 (the ratio of the index in 2017 to the index in 1990), and the estimated annual percentage change of age standardised mortality rate during 1990-2017. A P value of less than 0.05 was regarded as significant.

Patient and public involvement

Patients or the public were not involved in the design, data collection, analyses, or interpretation of this research.

Results

Disease burden and mortality estimates

According to the Global Burden of Disease Study 2017, DALYs due to chronic respiratory diseases ranged from 97.2 to 112.3 million a year from 1990 to 2017. An improvement in DALYs was seen in patients with asthma and pneumoconiosis, whereas patients with COPD and interstitial lung disease and pulmonary sarcoidosis showed worsening health (supplementary table 2). The number of deaths from chronic respiratory disease increased by 18.0%, from 3.32 (95% uncertainty interval 3.01 to 3.43) million in 1990 to 3.91 (3.79 to 4.04) million in 2017. Nevertheless, the age standardised mortality rate declined by an average of 2.41% (2.28% to 2.55%) annually during the same period, and differed widely between males and females both in 1990 and 2017.

In 2017, 3.20 (95% uncertainty interval 3.03 to 3.36) million people died from COPD, accounting for 81.7% of the total number of deaths from chronic respiratory diseases. The number of deaths due to COPD in 2017 was 23% more than in 1990 (supplementary table 2; supplementary fig 1). Figure 1 provides a global view of a wide range of age standardised mortality rates attributable to COPD in 2017. Estimates of mortality rates by country are presented in supplementary table 3. The age standardised mortality rates exceeded 100 per 100 000 people in Papua New Guinea (229.9 (95% uncertainty interval 192.8 to 274.0) per 100 000 people), North Korea, India, Myanmar, and Nepal.

Mortality rates below 10 per 100 000 people were seen in high income Asia (Japan, Singapore, Iraq, Kuwait, and Oman), some countries in Europe (Montenegro, Estonia, Latvia, and France), the Caribbean (Antigua and Barbuda, Barbados, Trinidad, and Tobago), North America (Bermuda, The Bahamas), and South America (Peru). From 1990 to 2017, the global age standardised mortality rate of COPD dropped by an average of 2.36% (95% uncertainty interval 2.21% to 2.50%) annually. Figure 2 shows that the country with the fastest decline in mortality was Singapore with a rate of 6.69% (6.52% to 6.86%). Nevertheless, the mortality rates in 22 countries increased, and the mortality in Georgia increased at the fastest rate (4.00%, 2.75% to 5.25%).

In 2017, 21.6 (95% uncertainty interval 20.5 to 22.7) thousand deaths were attributed to pneumoconiosis. The age standardised mortality rate of pneumoconiosis varied widely among countries (supplementary fig 2a), with the highest in Papua New Guinea (1.76 (1.23 to 2.50) per 100 000 people) and the lowest in Moldova (0.0041 (0.0035 to 0.0048) per 100 000 people). Countries with mortality rates above 0.5 per 100 000 people were Africa (Swaziland, Lesotho, Madagascar, Central African Republic, Somalia, and South Africa), Oceania (Papua New Guinea, Marshall Islands, and Solomon Islands), East Asia (North Korea and Taiwan), South America (Chile), and central Pacific Ocean (Kiribati). The age standardised mortality rate decreased from 0.52 (95% uncertainty interval 0.44 to 0.61) per 100 000 people to 0.28 (0.26 to 0.29) per 100 000 people globally, with an average decrease of 2.56% (2.44% to 2.68%) annually from 1990 to 2017 (supplementary figure 2c). Macedonia was estimated to be the country in which pneumoconiosis was decreasing most rapidly, with a decrease of 11.10% (10.28% to 11.92%) annually from 1990 to 2017. The mortality rates in 32 countries increased, and the greatest rate of increase was noted in Georgia (3.99%, 2.33% to 5.68%).

Supplementary figure 3a shows the global age standardised mortality rate of asthma with a large difference in the regional distribution in 2017. Mortality rates in two countries (Papua New Guinea and Kiribati) were estimated to exceed 50 per 100 000 people. Those countries with mortality rates of asthma below 0.5 per 100 000 people were in Europe (Italy, Greece, Bulgaria, Montenegro, Netherlands, Ukraine, Austria, Slovenia, Iceland, Portugal, and Switzerland), America (Canada and Colombia), and Asia (Armenia and Japan). An average decrease of 3.40% (95% uncertainty interval 3.25% to 3.55%) annually in the global age standardised mortality rate associated with asthma from 1990 to 2017 was seen. The largest decrease in the mortality rate was found in Korea (10.42%, 9.56% to 11.27%). Mortality rates were increased in only Zimbabwe and Lesotho (supplementary fig 3c).

In 2017, the age standardised mortality rates of interstitial lung disease and pulmonary sarcoidosis ranged from 0.23 (95% uncertainty interval 0.13 to 0.39) to 12.10 (7.74 to 14.53) per 100 000 people (supplementary fig 4a). Countries with the rates above 5 per 100 000 people were in South America (Peru, Bolivia, and Chile) and Asia (Maldives and Tajikistan). Some countries in Europe (Moldova, Montenegro, Macedonia, and Bulgaria), Africa (Burkina Faso, Liberia, and Cape Verde), and Asia (Oman and Philippines) had the lowest mortality rates—below 0.3 per 100 000 people. Unlike other chronic respiratory diseases, the global age standardised mortality rate due to interstitial lung disease and pulmonary sarcoidosis increased at an average of 0.97% (0.92% to 1.03%) a year from 1990 to 2017 (supplementary fig 4c). Mortality from interstitial lung disease and pulmonary sarcoidosis declined in 73 countries during the period. The country with the fastest decrease in the mortality rate annually from 1990 to 2017 was Russia (7.81%, 6.61% to 9.00%), and the fastest increase was noted in Greece (5.63%, 5.21% to 6.05%).

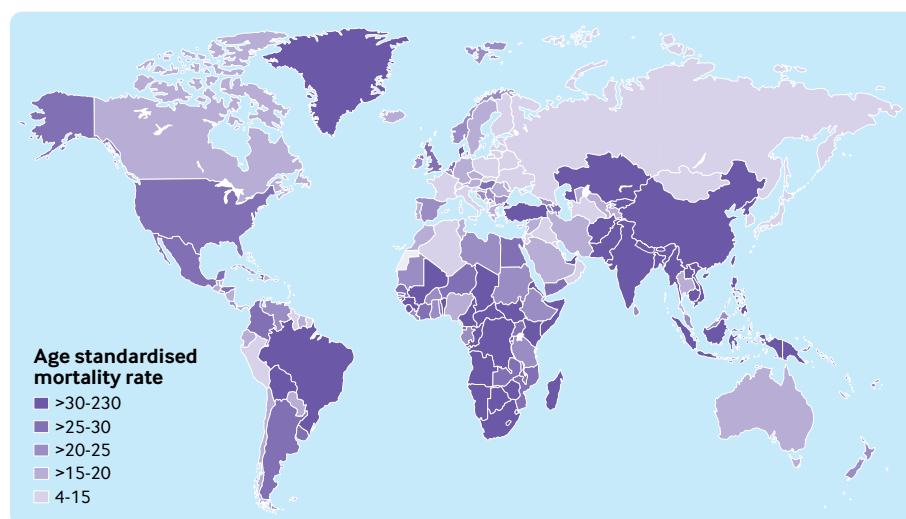


Fig 1 | Global age standardised mortality rate per 100 000 people of chronic obstructive pulmonary disease for both sexes in 195 countries and territories in 2017

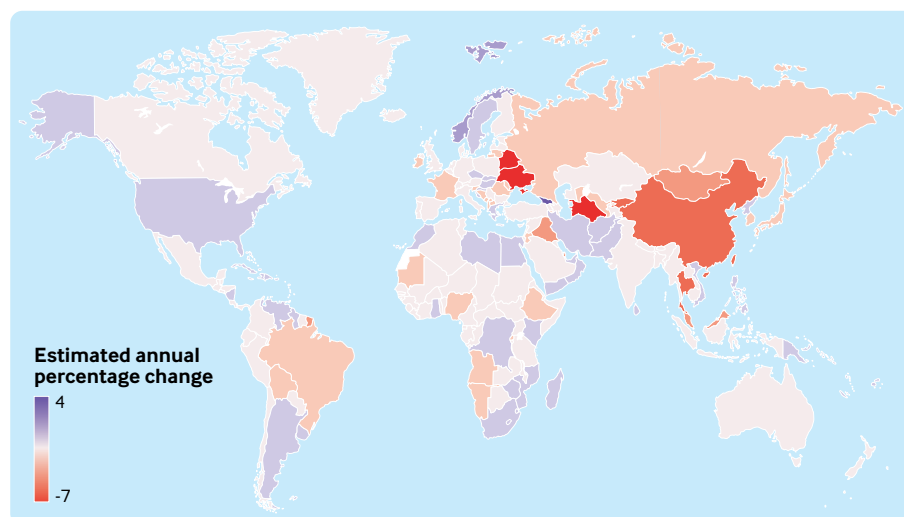


Fig 2 | Estimated annual percentage change in age standardised mortality rate per 100 000 people of chronic obstructive pulmonary disease for both sexes in 195 countries and territories from 1990 to 2017

Sex and age differences in mortality and DALY

Strong decreases were seen in the age standardised DALY rates and age standardised mortality rates of chronic respiratory diseases for both sexes from 1990 to 2017 (fig 3). Generally, the mortality rate of chronic respiratory diseases in males was higher than in females. For asthma, the mortality gap between males and females narrowed during 1990-2017, suggesting that the rate dropped more quickly in males than females.

Deaths attributed globally to COPD, pneumoconiosis, asthma, and interstitial lung disease and pulmonary sarcoidosis in 1990 and 2017 by age and sex are shown in supplementary figure 5 and figure 4, respectively. The number of deaths from all four types of chronic respiratory diseases increased with age and rose sharply in those aged 70 and older, although asthma is more common among children than adults.

Correlation between the Socio-demographic index and estimates of mortality and DALYs

Associations between the Socio-demographic index and age standardised mortality rates due to COPD, pneumoconiosis, asthma, and interstitial lung disease and pulmonary sarcoidosis are shown in figure 5. For COPD and asthma, the mortality rates showed a downward trend for all five Socio-demographic index regions between 1990 and 2017, decreasing from regions with a low index to those with a high index. Moderate to strong negative correlations were seen between the mortality rates and Socio-demographic index (supplementary fig 6).¹⁵ For pneumoconiosis, a negative correlation between the mortality rate and Socio-demographic index was seen. Nevertheless, the mortality rates in regions with a high and middle Socio-demographic index were higher than in regions with a low middle and high middle index. The mortality rate of interstitial lung disease and pulmonary sarcoidosis was positively associated with

the Socio-demographic index. Except for regions with a high middle Socio-demographic index, the mortality rates in the four other index regions showed an increasing trend from 1990 to 2017. No correlation was found between the estimated annual percentage change in the age standardised mortality rates of the four types of chronic respiratory diseases during 1990-2017 and the change in the Socio-demographic index between the same dates (supplementary fig 7). Similarly, the relation between the Socio-demographic index and age standardised DALY rates resembled those between the Socio-demographic index and mortality rates of the four types of chronic respiratory diseases (supplementary figs 8 and 9).

Risk factors

In 2017, the leading risk factor for deaths and disability due to COPD was tobacco use, including smoking and secondhand smoke, which accounted for 1.41 (95% uncertainty interval 1.27 to 1.54) million deaths from COPD and 33.01 (8.94 to 36.51) million DALYs. Pollution from particulate matter was the next most important risk factor with 1.00 (0.69 to 1.28) million deaths and 25.12 (17.26 to 31.94) million DALYs; supplementary fig 10a and 11). Besides smoking, the mortality attributable to secondhand smoke was too great to ignore. In 2017, about 8.3% (0.27 (0.14 to 0.41) million of 3.20 (3.03 to 3.36) million) of deaths from COPD were due to secondhand smoke (supplementary fig 10b). The effect of smoking on deaths from COPD was greater in males than in females (supplementary fig 10c). Although the rates continued to decline in both sexes, a greater decline occurred in males, and thus disparity between the sexes in deaths due to COPD attributable to tobacco use narrowed over time (supplementary fig 10c). The age standardised mortality rate attributable to household air pollution from solid fuels decreased by 73.5% from 17.78 (95% uncertainty interval 13.01 to 22.29) per 100 000 people in 1990 to 4.72

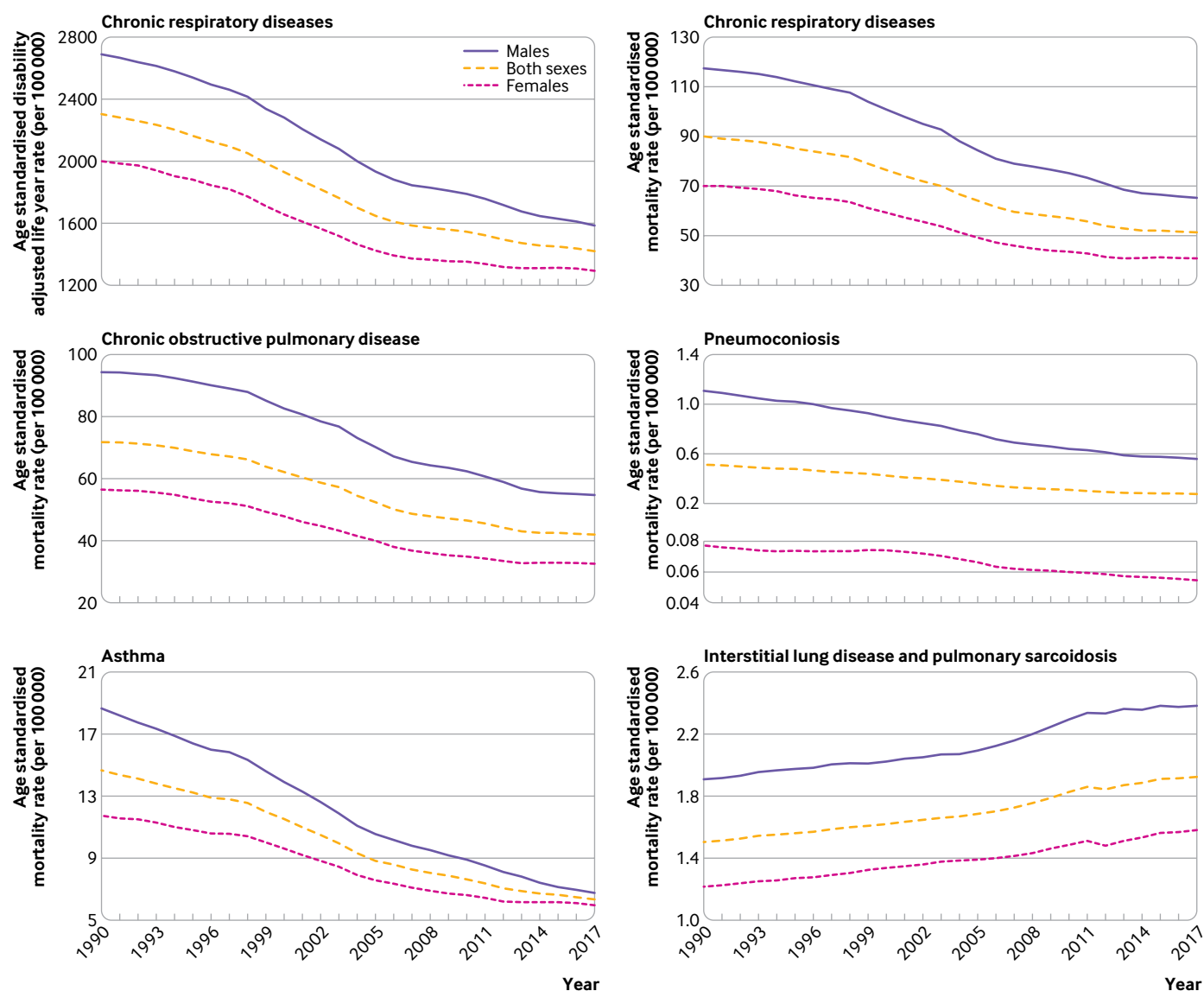


Fig 3 | Age standardised disability adjusted life years and age standardised mortality rate per 100 000 people of chronic respiratory diseases in males (men and boys), females (women and girls), and both sexes from 1990 to 2017. Age standardised mortality rates of chronic obstructive pulmonary disease, pneumoconiosis, asthma, and interstitial lung disease and pulmonary sarcoidosis by sex from 1990 to 2017

(3.23 to 6.28) per 100 000 people in 2017, and thus pollution from ambient particulate matter has become the major risk factor for deaths from COPD since 2002 (supplementary fig 10d).

Significant negative correlations between the Socio-demographic index and age standardised mortality rate of COPD attributable to risk factors other than tobacco were seen (supplementary fig 12). For particulate matter pollution ($R=-0.793$, $P<0.001$) and occupational risks ($R=-0.6989$, $P<0.001$), the correlations were moderate to strong.¹⁵ In regions with a high, high middle, middle, and low middle Socio-demographic index, tobacco was the most important risk factor for deaths from COPD (fig 6). Particulate matter pollution explained most of the deaths from COPD in regions with a low Socio-demographic index. The proportion of mortality attributable to tobacco decreased as the Socio-demographic index

declined. In 1990, the main level 4 risk factor for the age standardised mortality rate and age standardised DALYs from asthma was smoking (supplementary figs 13a and 11b). The mortality rate attributable to smoking declined by 68.7% from 2.36 (95% uncertainty interval 1.12 to 3.54) per 100 000 people in 1990 to 0.74 (0.37 to 1.14) per 100 000 people in 2017, especially in males (supplementary fig 13b). Furthermore, a high body mass index was identified as the most critical risk factor for DALYs due to asthma since 2003, accounting for the most deaths from asthma since 2013 (supplementary figs 11b and 13a). The mortality rate of asthma attributable to a high body mass index in males showed a sharp decline, and has been lower in males than in females since 2011 (supplementary fig 13c). Occupational asthmagens were also strong risk factors for asthma, explaining 6.7% (0.42 (95% uncertainty interval 0.27 to 0.57) of

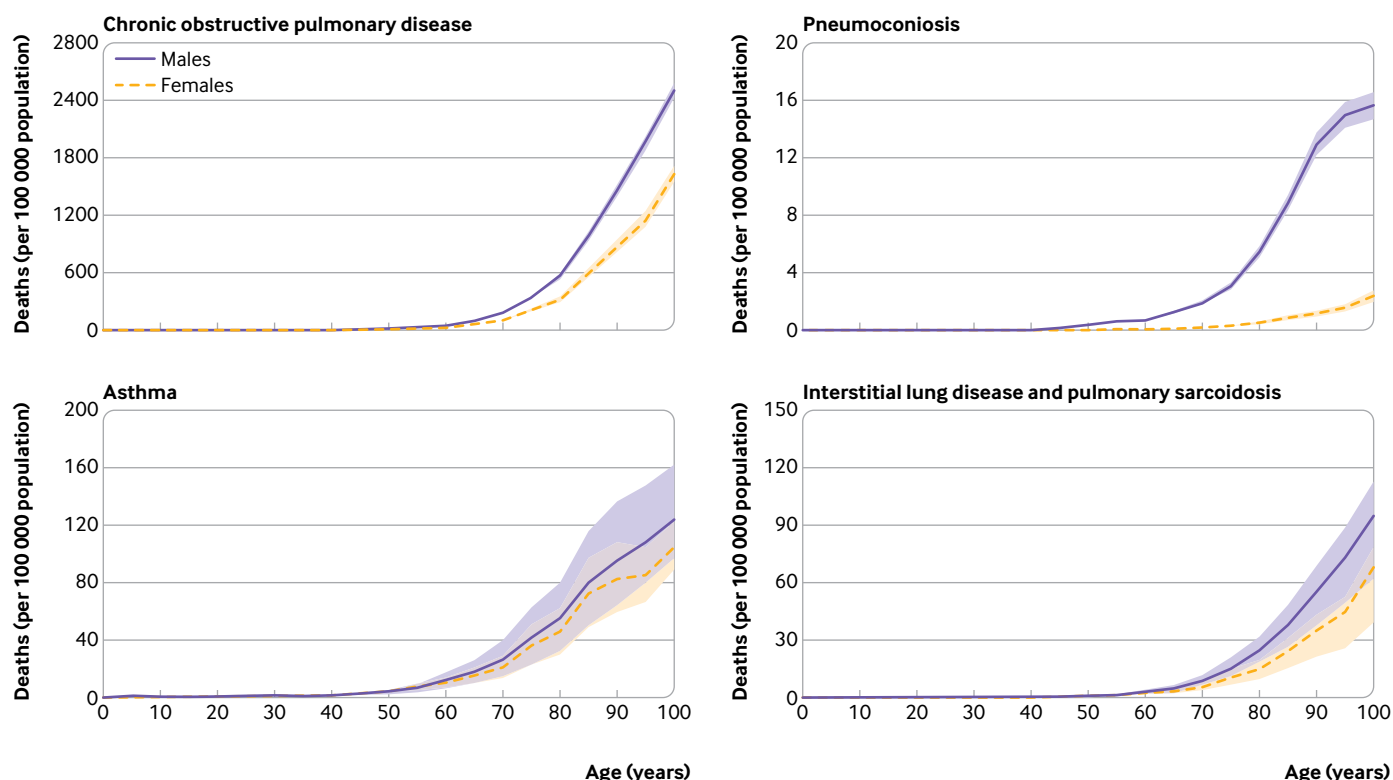


Fig 4 | Global mortality rates per 100 000 people of chronic obstructive pulmonary disease; pneumoconiosis; asthma; and interstitial lung disease and pulmonary sarcoidosis by age in males (men and boys) and females (women and girls) in 2017. Shading indicates 95% uncertainty intervals

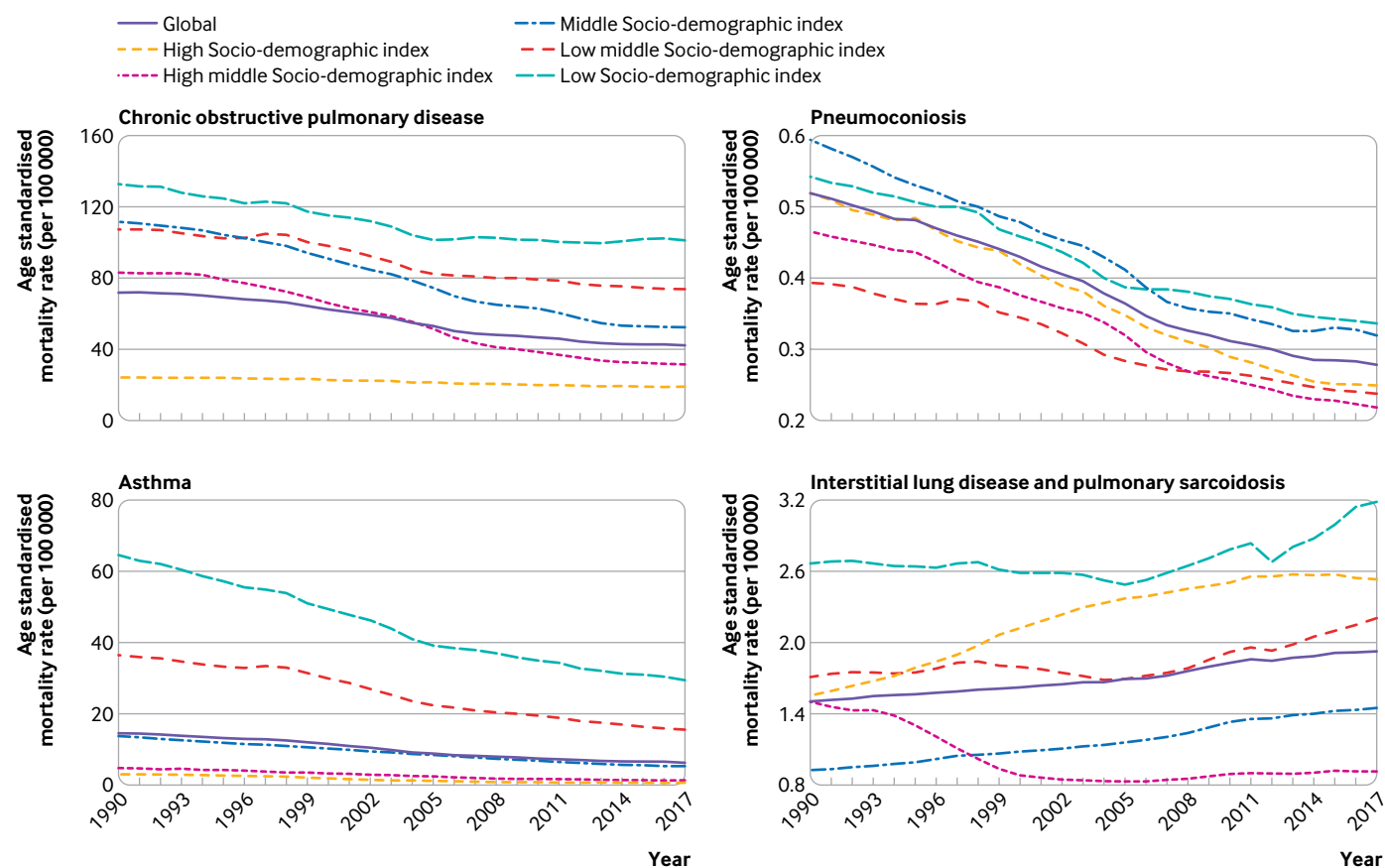


Fig 5 | Age standardised mortality rates per 100 000 people of chronic obstructive pulmonary disease; pneumoconiosis; asthma; and interstitial lung disease and pulmonary sarcoidosis, grouped by Socio-demographic index quintiles from 1990 to 2017

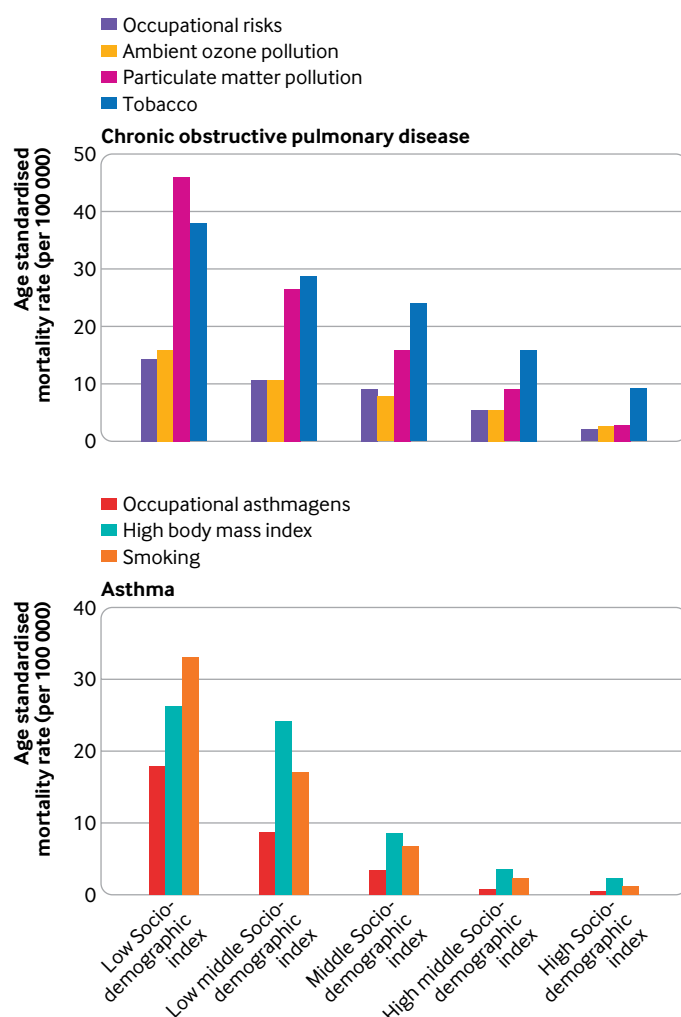


Fig 6 | Contribution of pollution by occupational risks, ambient ozone pollution, particulate matter, and tobacco to the age standardised mortality rates per 100 000 people of chronic obstructive pulmonary disease in locations grouped by Socio-demographic index quintiles in 2017. Contribution of occupational asthmagens, a high body mass index, and smoking to the age standardised mortality rates of asthma in locations grouped by Socio-demographic index quintiles in 2017

6.33 (4.34 to 8.17) deaths due to asthma per 100 000 people) in 2017.

Significant moderate to strong negative correlations were seen between the Socio-demographic index and age standardised mortality rates of asthma attributable to smoking, a high body mass index, and occupational asthmagens ($R=-0.7084$, $P<0.001$; $R=-0.7129$, $P<0.001$; $R=-0.8465$, $P<0.001$, respectively; supplementary fig 14). In countries with a low Socio-demographic index, smoking was the most important risk factor for asthma, whereas a high body mass index accounted for most mortality in the other four Socio-demographic index regions (fig 6).

Discussion

The global and national burden of chronic respiratory diseases during 1990 to 2017 was described in this study. Increasing trends for deaths and loss of health due to chronic respiratory diseases were seen. The age

standardised mortality rate and age standardised rate of DALYs from chronic respiratory diseases decreased. Interstitial lung disease and pulmonary sarcoidosis showed increasing trends for an increasing age standardised mortality rate and age standardised DALY rate, in contrast to three other types of respiratory disease— COPD, pneumoconiosis, and asthma.

To investigate the factors explaining the changes in mortality and DALYs due to chronic respiratory diseases from 1990 to 2017, the effects of sex, age, social development, and risk exposures were examined. Differences in the mortality rates due to chronic respiratory diseases between males and females were seen, especially for COPD and pneumoconiosis. A male predominance was noted in the morbidity of COPD and pneumoconiosis, and thus the relatively higher death rates seen in males could be related to the higher prevalence of chronic respiratory diseases in males than females.

In 1990 and 2017, deaths from chronic respiratory diseases increased with age, especially in people aged 70 and older. Unlike the distinct age trends in morbidity and mortality from asthma, the prevalence and mortality due to three other chronic respiratory diseases were largely consistent with age and age dependent. Therefore, the heavy burden of chronic respiratory diseases is likely to increase as the worldwide population ages.

In 2017, chronic respiratory diseases were an important public health concern and leading cause of disease, with a large proportion attributable to COPD and asthma. Considerable heterogeneity in the mortality rates of the four types of chronic respiratory diseases existed across countries in 2017. Countries with the highest mortality rate had more than a 50-fold higher rate of deaths than the countries with the lowest rate.

Mortality and DALYs were stratified by Socio-demographic index, in order to predict mortality patterns and identify areas needing additional support. The Socio-demographic index level was identified as a key factor affecting the death rate and loss of health, possibly explaining regional variations. For COPD, all countries with mortality rates exceeding 100 per 100 000 people were low and low middle regions, and 12 (80%) of 15 countries with rates below 10 per 100 000 people were high and high middle regions. Ten (77%) of 13 countries with mortality rates of pneumoconiosis above 0.5 per 100 000 people were low and low middle regions. The two countries (Papua New Guinea and Kiribati) with rates of asthma exceeding 50 per 100 000 people were both regions with a low Socio-demographic index. For interstitial lung disease and pulmonary sarcoidosis, the countries with rates above 5 per 100 000 people were low middle (Bolivia and Tajikistan), middle (Peru and Maldives), and high middle (Chile) regions. Most of those countries with the greatest mortality increase and decrease were regions with a high and high middle Socio-demographic index, and the change of the Socio-demographic index in these regions was relatively small between 1990 and 2017.

Negative correlations between the Socio-demographic index and mortality rates of COPD, pneumoconiosis, and asthma were seen. As no association between the Socio-demographic index and incidence of COPD was found, and a weak correlation between the Socio-demographic index and incidence of asthma was identified (supplementary fig 15), the low mortality in countries with a high Socio-demographic index reflects better access to health services and improved treatments. Correlations between the Socio-demographic index and incidence of pneumoconiosis, and between the Socio-demographic index and mortality from pneumoconiosis were both weak, suggesting that treatment has little effect on mortality. As the mortality and DALYs due to interstitial lung disease and pulmonary sarcoidosis increased with the Socio-demographic index, they are expected to impose increasing burdens on individuals and societies due to the global rise in Socio-demographic index levels.

Tobacco is a major risk factor for COPD, but other environmental and occupational exposures might also contribute to the disease. According to the Global Burden of Disease Study 2017, the leading cause of mortality and loss of health due to COPD remained tobacco use. Sex disparities in the mortality attributable to smoking were smaller even when a further decline of the smoking rate in females was seen. Although the prevalence of smoking decreased towards lower levels of the Socio-demographic index,² the mortality attributable to tobacco was higher in regions with a low and low middle Socio-demographic index. Apart from smoking, exposure to secondhand smoke was also an important contributing factor. Globally, more than a third of children and non-smokers were regularly exposed to secondhand smoke.¹⁶

Long term exposure to air pollution was reported to increase mortality from COPD. As the proportion of households cooking with solid fuels decreased worldwide,¹⁷ ambient particulate matter pollution became the predominant risk factor for mortality from COPD since 2002. A strong negative correlation between the mortality rate attributable to particulate matter pollution and the Socio-demographic index was seen. Pollution from particulate matter consistently contributed most to deaths from COPD in regions with a low Socio-demographic index.

Ambient ozone was the second most important air pollutant after particulate matter. Compelling evidence indicates that ambient ozone has increased the death rate from chronic low respiratory diseases.¹⁸ The health effects were related to ozone exposure, even at concentrations below national standards in the United States, and were most pronounced for low income people.¹⁹ Our study showed a negative correlation between the mortality rate attributable to ambient ozone and the Socio-demographic index in 2017.

Estimates suggested that more than 20% of instances of COPD in 2010 were attributable to occupational exposure.²⁰ An additive effect of smoking and occupational exposure was seen, increasing the

risk for COPD.^{20 21} During the 27 years of this study, the mortality rate attributable to occupational risks decreased, and was negatively associated with the Socio-demographic index in 2017.

Smoking can cause respiratory diseases other than COPD, such as asthma. Parental smoking was reported to be related to the risk of development of asthma in offspring.²² A 16 year prospective cohort study showed that smoking contributed to the incidence of adult onset asthma.²³ In our study, smoking was the major risk factor for mortality and loss of health in patients with asthma until 2013. A negative correlation between the Socio-demographic index and mortality rate from asthma, attributable to smoking, was shown. Furthermore, smoking was identified as the largest contributor to asthma related deaths in low Socio-demographic index regions, which indicates an urgent need to improve tobacco control in developing countries.

Previous studies have shown an association between a high body mass index and asthma, and high body mass index had a greater effect in females,²⁴ middle aged individuals, and elderly individuals.²⁵ Maternal obesity poses an increased risk for asthma in children.²⁶ Obese patients had a higher risk of exacerbations and poorer asthma control.²⁷ Moreover, positive effects of weight loss on outcomes related to asthma have been confirmed.²⁸ According to the Global Burden of Disease Study 2017, a high body mass index has accounted for the most deaths caused by asthma since 2013 and contributed the most to DALYs since 2003. Unlike smoking, obesity was not widely recognised as a modifiable risk factor. As the prevalence of obesity continues to increase at a worrying rate worldwide, weight loss should be included in the management of obese patients with asthma. From 1990 to 2017, mortality attributable to a high body mass index showed a decreasing trend, with a steeper slope in males, which resembles the temporal trend in mortality from asthma attributed to smoking. The effect of obesity on asthma has been greater in females than in males since 2010. Although the proportion of mortality explained by a high body mass index was highest in regions with a high and middle Socio-demographic index, mortality attributable to a high body mass index was negatively associated with the Socio-demographic index, indicating a larger burden in low index regions.

Occupational asthmagens were the second largest environmental and occupational risk factors for asthma. Exposure to occupational asthmagens, including gas, smoke, dust, and other agents, was associated with the exacerbation²⁹ and uncontrolled onset of asthma in adults.³⁰ The number of suspected and recognised asthmagens has tripled since 2000, which is likely to improve the assessment of asthma due to occupational exposure.

Strengths and limitations of this study

This study provides comprehensive estimates of mortality and DALYs due to chronic respiratory

diseases by age, sex, region, and disease for the period 1990 to 2017. To investigate the explanatory factors for the contemporary regional variations in mortality and DALYs and the unequal distribution of improvements during the 27 years, the attribution of risk factors, including the Socio-demographic index and various risk exposures, was examined.

The limitations of our study are the case definitions of various chronic respiratory diseases. Firstly, civil registration and statistics systems are key sources of vital statistics for mortality rates, but the population coverage with these systems has been disappointing. Verbal autopsy, which cannot accurately determine the cause of death, is the best option for estimating the mortality rates in countries without fully functional vital registration systems. As civil registration and vital statistics systems provide essential information for public health policies and disease preventions,³¹ strengthening of these systems is important for public health. Secondly, the variable rates of misdiagnosis across countries should be taken into consideration. As most patients with COPD and asthma were identified by spirometry, a lack of spirometric evaluation leads to misdiagnosis and underdiagnosis, which was more serious in regions with a low Socio-demographic index. Availability of spirometry could enhance diagnostic accuracy. Additionally, different diagnostic thresholds for air obstruction (expiratory volume in one second/forced vital capacity <0.70, or the lower limit of normal) influence the diagnosis and estimates of prevalence and mortality of COPD.³² Spirometric criteria and case definition need to be standardised.

Conclusion and policy implications

This study showed that the number of global deaths and DALYs from chronic respiratory diseases increased from 1990 to 2017, while the age standardised mortality rate and age standardised DALY rate decreased, with a more profound decline in males. Overall, a low Socio-demographic index was the most important factor that impeded progress in reducing mortality in developing countries. Ageing and risk exposures, including smoking, environmental pollution, and a high body mass index, are the main drivers of mortality, and should receive more attention with supportive policies.

Contributors: MX and XLI contributed equally. XLI conceived the study and drafted the manuscript. XLI and MX collected and analysed the data. MX and XLI revised and approved the final version of the manuscript. XC and MG participated in the data preparation and provided important comments on the manuscript. XLI, MX, and XLI are the guarantors. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Ethical approval: This study does not contain personal or medical information about an identifiable living individual, and animal subjects were not involved in the study.

Data sharing: Data sources and code used in the Global Burden of Disease Study 2017 are available on the internet. (<http://ghdx.healthdata.org/gbd-results-tool>)

The lead author (XLI) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that discrepancies from the study as planned have been explained.

Dissemination to participants and related patient and public communities: The results of this study will be disseminated through the institutional websites.

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Web appendix: Supplemental information