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Long-term trends in the burden of asthma in China: a joinpoint regression and age-period-cohort analysis based on the GBD 2021

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Abstract

Background To develop effective strategies for controlling asthma, a thorough assessment of its disease burden is essential. In this study, we examined long-term trends in the asthma burden in China over the past three decades and analyzed its epidemiological features.

Methods We assessed the burden of asthma in China via the global burden of disease (GBD) 2021 database, focusing on prevalence, incidence, mortality, years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs). Additionally, we employed joinpoint analysis and age-period-cohort (apc) methods to interpret the epidemiological characteristics of asthma. Finally, we analyzed the attributable burden of asthma to gain a comprehensive understanding of its impact.

Results The age-standardized incidence rate (ASIR) and mortality rate (ASMR) for both sexes in China shifted from 524.81 (95% UI: 421.31, 672.76) to 314.17 (95% UI: 283.22, 494.10) and from 5.82 (95% UI: 4.46, 8.50) to 1.47 (95% UI: 1.15, 1.79) per 100,000 population between 1990 and 2021. According to joinpoint analysis, the average annual percentage change (AAPC) in the age-standardized incidence rate was − 1.2 (95% CI: − 1.4, − 1.1), indicating a gradual but fluctuating decline (with significant turning points in 2005 and 2014). The apc fitting results suggest that the prevalence is now lower than it was in the past and that the relative prevalence risk is high among adolescents and middle-aged to elderly individuals, possibly due to different pathophysiological mechanisms. In 2021, the primary asthma-related burdens were metabolic risks, especially obesity.

Conclusions In conclusion, we found that the disease burden of asthma in China has significantly decreased. However, it remains a major concern among adolescents and elderly individuals. Metabolic risk factors, particularly obesity, are the main contributors to the asthma burden. It is essential to address specific risk factors and develop targeted public health strategies for different age groups.

Keywords Asthma, Disease burden, GBD 2021, Joinpoint regression, Age-period-cohort analysis, Epidemiological study

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Introduction

Asthma is a prevalent chronic airway inflammatory disease with varying prevalence rates and disability-adjusted life years (DALYs) over time. Furthermore, asthma has been recognized as a significant public health concern since the 1970s, as it poses a long-term threat to the lives and health of people worldwide [1, 2]. In 2021, asthma affected approximately 298 million people globally, with a prevalence of approximately 19 people per 1000 in China.

However, asthma is largely undiagnosed and undertreated in China [3]. This phenomenon is particularly prevalent among children and young adults with cough-variant phenotypes [4, 5]. Increasing awareness of asthma and promoting standardized treatment in clinical settings are essential steps to alleviate the disease burden. Furthermore, individuals with severe asthma face even greater challenges than those without, making it imperative to increase their quality of daily life. Therefore, clarifying the burden of asthma among the Chinese population at different times can aid in developing more targeted health policies to reduce disease risk. Although previous studies have systematically analyzed the burden of allergic disorders from 1990 to 2019, existing research is limited in scope and has focused only on a single asthma subtype [6]. There is a need for more analysis of temporal changes to provide a more fundamental basis for decision-making. Systematically evaluating data from other available sources may offer valuable support for policymakers, identify effective disease control strategies to minimize the burden, and help fill existing knowledge gaps.

This article presented the current situation of specific causes of mortality, morbidity, and DALYs associated with asthma in China from 1990 to 2021. We explored the risk of asthma incidence over the past 30 years in China via joinpoint regression and the apc models. Furthermore, we focused on the main driving factors influencing asthma, including metabolism, environmental and social risk factors. Data from the global burden of disease (GBD) 2021 were used to identify disparities in the asthma burden in China and promote the development of a national-level strategy for improvement through the healthcare system.

Methods

Overview

The GBD 2021 report encompasses 371 diseases and injuries across 204 countries and regions, incorporating estimations from various models for disease and injury outcomes [7]. The primary statistical methods and mathematical models employed for estimation include the cause of death ensemble model (CODEm), the spatiotemporal Gaussian process regression (STGPR), and the Bayesian meta-regression tool DisMod-MR. These are utilized to estimate prevalence, incidence, mortality, years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs). Such estimates are stratified by cause, age, sex, year, and location. YLLs are the number of years lost due to disease-related early death, calculated by multiplying number of deaths by the standard life expectancy at the age that death occurred. YLDs are the number of years lived in less than full health due to disease-caused disability, calculated by multiplying prevalence of the condition by their respective disability weights. DALYs measure the total years of healthy life lost from the onset of a disease to death. DALYs were calculated as the sum of YLDs and YLLs. 95% uncertainty intervals (UIs) were generated for all final estimates as the 2.5th and 97.5th percentiles values of 500 draws. Detailed descriptions of data resources, definitions, statistical modeling, and initiatives to increase data quality were available in previous publications [7, 8]. Data on asthma burdens in China from 1990 to 2021 were collected via the Global Health Data Exchange GBD Results Tool (https://vizhub.healthdata.org/gbd-results/). This study did not require ethical clearance, as it utilized publicly available data.

Joinpoint regression analysis

Joinpoint regression models assess the variation in the trends in incidence rates by identifying the combinations of trends that provide a statistically significantly better fit to a data series than a single-trend line fitted by Poisson regression or time series models [9]. This procedure tends to determine the number of joinpoints that are adequate for assessing significant changes in incidence trends over time. Specifically, this technique is designed to identify the calendar year (joinpoint) where statistically significant abrupt changes in temporal trends occur [10]. Joinpoint (version 4.9.1.0; National Cancer Institute, Rockville, MD, USA; https://surveillance.cancer.gov/joinpoint/download) was used to create this model. We also calculated the annual percentage change (APC) and average annual percentage change (AAPC) and investigated whether the fluctuation trend in different parts was statistically significant by comparing the AAPC to zero. A statistically significant P value was less than 0.05.

Age-period-cohort (apc) analysis

The apc model reflects a disease's incidence or mortality time trend by age, period, and cohort. Estimating the distinct effects of each component presents difficulties due to the linear associations among age, period, and cohort [11]. This is attributed to the high correlation among age, period, and cohort within the apc model, where their interactions and complexities hinder the independent estimation of their respective effects [12]. This study used the technique of apc model analysis, which was thoroughly explained by Carstensen from the Lexis diagram [13]. GBD classified people under 5 years and over 95 years into one group, and for apc model fitting, the age groups were defined as < 5, 5–9, 10–14…, > 95. For a 5-year period (1990–1994, 1995–1999…, 2014–2019, > 2020), the total number of cases of incidence or death, as well as the cumulative incidence and mortality rates for various age groups, were calculated. We performed apc model fitting via R (version 4.3.2; http://www.r-project.org) and Stata (version 18).

Results

Descriptive analysis

In 2021, the prevalence of asthma in China was 25.01 million cases (95% UI: 20.90–30.45 million), with an incidence of 3.93 million new cases (95% UI: 3.18–5.14 million), and 0.026 million deaths attributed to asthma (95% UI: 0.020–0.032 million). From 1990 to 2021, there were decreases of 25.39% in prevalence, 32.59% in incidence, and 27.78% in asthma-related deaths. The number of DALYs caused by asthma in China decreased by 38.13% from 1990 to 2021, reaching 1.46 million (95% UI: 1.07–1.94 million). Additionally, YLDs showed a similar downward trend, decreasing from 1.33 million in 1990 (95% UI: 0.84–2.01 million) to 0.99 million in 2021 (95% UI: 0.62–1.48 million), a decrease of 25.56%. YLLs also followed this trend. The ASPRs, ASIRs, ASMRs, DALYs, YLDs, and YLLs of asthma in 2021 were 1956.49, 364.17, 1.47, 103.76, 78.00, and 25.76 per 100,000 population, respectively. The all-age numbers and age-standardized rates with 95% UI for males and females were presented in Tables 1 and 2. Trends in asthma burden across different years for various indicators were shown in Fig. 1. Throughout the years 1990–2021, all asthma-related measures demonstrated a predominantly declining trend in China, punctuated by subtle variations across the timeline.

Joinpoint regression analysis

We conducted a joinpoint regression analysis on the age-standardized incidence rate of asthma from 1990 to 2021 (Fig. 2). There was a decreasing trend from 1990 to 2005 ($APC_{1990\sim1997} = -1.8$, $APC_{1997\sim2005} = -4.6$), followed by a major increase in the annual incidence rate after 2005, which continued until 2014 ($APC_{2005\sim2014} = 2.1$). After 2014, there was a slight downward trend ($APC_{2014\sim2021} =$

Table 1 Prevalence, incidence, deaths, YLLs, YLDs, and DALYs in 1990 for asthma in China

Measure	All ages cases (million)			Age-standardized rates per 100,000 people		
	Male	Female	Both	Male	Female	Both
Prevalence	17.77 (14.45, 22.21)	15.76 (12.92, 19.19)	33.52 (27.44, 41.41)	3197.12 (2649.07, 3951.03)	2979.75 (2511.40, 3603.05)	3087.89 (2583.55, 3782.05)
Incidence	3.22 (2.56, 4.19)	2.60 (2.09, 3.30)	5.83 (4.64, 7.50)	561.78 (448.43,725.78)	485.03 (392.61, 617.31)	524.81 (421.31, 672.76)
Deaths	0.019 (0.014, 0.032)	0.017 (0.011,0.023)	0.036 (0.029, 0.052)	7.11 (4.95, 12.28)	4.96 (3.10, 7.21)	5.82 (4.46, 8.50)
YLDs	0.79 (0.44, 1.07)	0.62 (0.39, 0.93)	1.33 (0.84, 2.01)	126.64 (79.99, 190.53)	117.02 (74.15, 173.26)	121.82 (77.10, 182.02)
YLLs	0.57 (0.43, 0.87)	0.46 (0.30, 0.60)	1.03 (0.81, 1.38)	143.48 (105.16, 231.94)	106.55 (68.91, 143.47)	122.77 (97.31, 170.00)
DALYs	1.28 (0.98, 1.73)	1.08 (0.78, 1.45)	2.36 (1.82, 3.11)	270.12 (208.31, 378.76)	223.57 (162.08, 298.24)	244.58 (191.12, 316.63)

Data in parentheses are 95% Uncertainty Intervals (UI)

DALYs disability-adjusted life years; *YLLs* years lost due to premature mortality; *YLDs* years lived with disability

Table 2 Prevalence, incidence, deaths, YLLs, YLDs, and DALYs in 2021 for asthma in China

Measure	All ages cases (million)			Age-standardized rates per 100,000 people		
	Male	Female	Both	Male	Female	Both
Prevalence	14.03 (11.64, 17.25)	10.98 (9.21, 13.22)	25.01 (20.90, 30.45)	2155.10 (1729.36, 2757.98)	1746.77 (14.3.11, 2206.59)	1956.49 (2491.87, 1566.68)
Incidence	2.27 (1.83, 3.00)	1.66 (1.36, 2.13)	3.93 (3.18, 5.14)	404.54 (312.57,547.88)	319.56 (248.24, 429.99)	364.17 (283.22, 494.10)
Deaths	0.015 (0.010, 0.019)	0.011 (0.008, 0.016)	0.026 (0.020, 0.032)	1.95 (1.38, 2.50)	1.14 (0.78, 1.59)	1.47 (1.15, 1.79)
YLDs	0.55 (0.35, 0.83)	0.43 (0.27, 0.64)	0.99 (0.62, 1.48)	86.03 (53.24, 131.93)	69.47 (42.64, 105.42)	78.00 (48.10, 119.90)
YLLs	0.28 (0.20, 0.37)	0.20 (0.14, 0.28)	0.48 (0.38, 0.58)	32.85 (23.28, 42.82)	20.21 (14.05, 28.26)	25.76 (20.59, 31.04)
DALYs	0.83 (0.61, 1.14)	0.63 (0.45, 0.84)	1.46 (1.07, 1.94)	118.88 (83.53, 166.81)	89.68 (62.21, 124.99)	103.76 (72.50, 145.46)

Data in parentheses are 95% Uncertainty Intervals (UI)

DALYs disability-adjusted life years; *YLLs* years lost due to premature mortality; *YLDs* years lived with disability

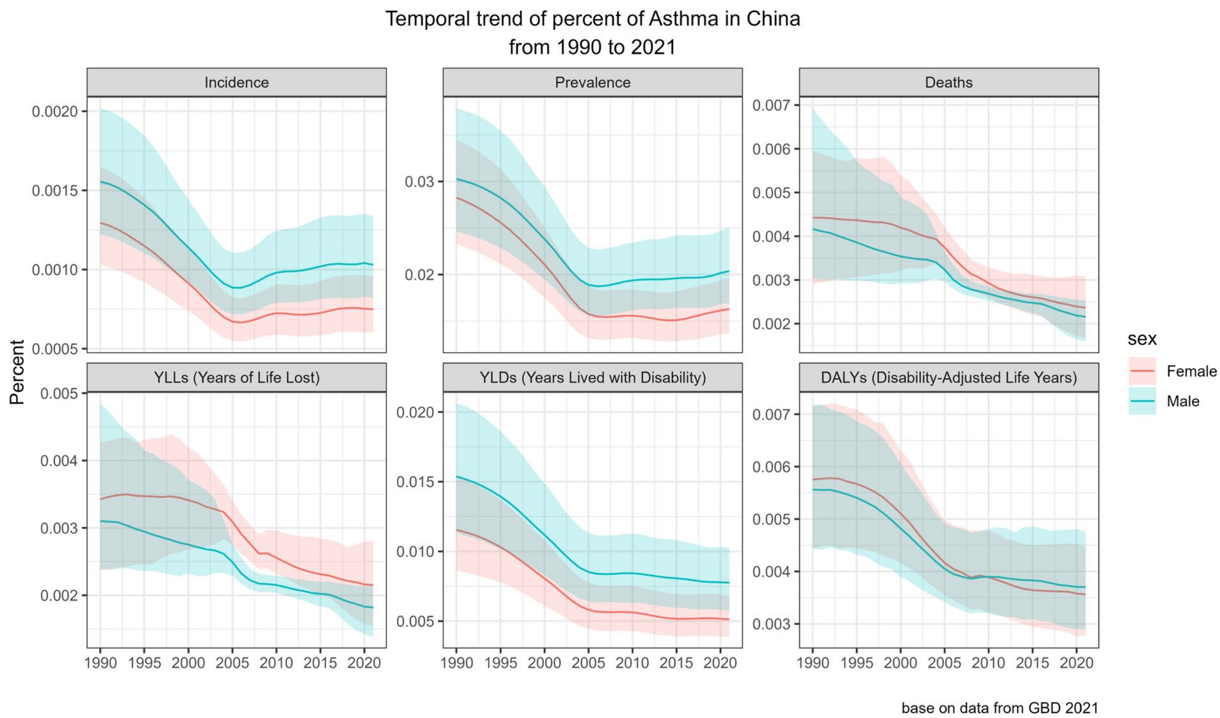

Fig. 1 Trends in asthma burden across different years for various indicators. The Y-axis represents the percentage of the total disease burden attributable to each indicator, whereas the X-axis represents the years. The red line and shaded area indicate the predicted curve and confidence interval for females, whereas the blue line represents males. The six graphs illustrate the proportions of different indicators within the overall disease burden

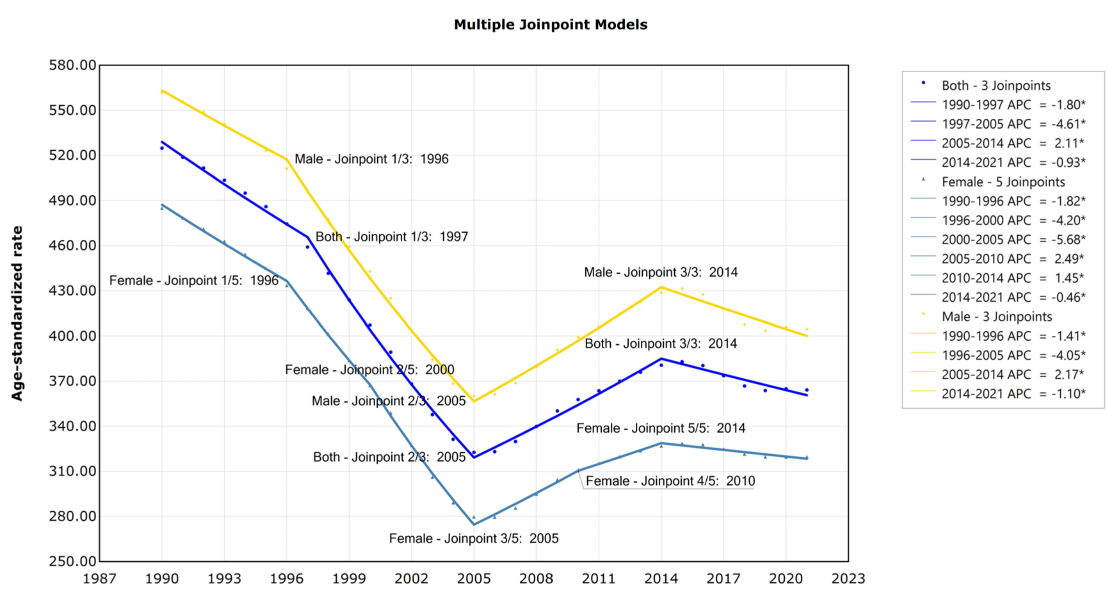

Fig. 2 Joinpoint regression analysis of age-standardized asthma incidence rates in China from 1990 to 2021. The joinpoint regression model is used to identify significant changes in the trend (joinpoints) and to calculate the annual percentage change for each trend segment. This figure illustrates the trend segments and joinpoints, which typically coincide with significant public health developments or events

Table 3 Joinpoint regression analysis: trends in age-standardized incidence rates (per 100,000) among both sexes, males, and females in China, 1990–2021

Gender	Age-standardized rates in terms of incidence (ASIR)		
	Period	**APC (95% CI)**	**AAPC (95% CI)**
Both	1990–1997	− 1.8 (− 2.1, − 1.5)	− 1.2 (− 1.4, − 1.1)
	1997–2005	− 4.6 (− 4.9, − 4.4)	
	2005–2014	2.1 (1.9, 2.3)	
	2014–2021	− 0.9 (− 1.2, − 0.6)	
Male	1990–1996	− 1.4 (− 1.7, − 1.1)	− 1.1 (− 1.2, − 1.0)
	1996–2005	− 4.1 (− 4.3, − 3.8)	
	2005–2014	2.2 (1.9, 2.4)	
	2014–2021	− 1.1 (− 1.4, − 0.8)	
Female	1990–1996	− 1.8 (− 2.0, − 1.7)	− 1.4 (− 1.5, − 1.3)
	1996–2000	− 4.2 (− 4.6, − 3.8)	
	2000–2005	− 5.7 (− 6.0, − 5.4)	
	2005–2010	2.5 (2.2, 2.8)	
	2010–2014	1.4 (0.9, 2.0)	
	2014–2021	− 0.5 (− 0.6, − 0.3)	

AAPC average annual percent change presented for the full period; *APC* annual percent change; *CI* confidence interval

− 0.9), and the overall trend showed a fluctuating downward trend (AAPC= − 1.2). We conducted a subgroup analysis and found that the trends in the incidence rates of males and females were similar, with a fluctuating downward trend (Fig. 2), and with a peak around 2014. After 2014, the rate gradually decreased, but the incidence rate for males consistently remained higher than that for females. Table 3 showed the AAPCs in asthma incidence rates over three decades, which males had a higher AAPC than females did.

Effects of age, period, and cohort on the prevalence rate

We explored the changes in the ASPRs of asthma in China from 1990 to 2021 across different periods. Each age group was represented by different cohorts in different periods. Figure 3A depicted the prevalence trends by age for 1990 through 2021. Different colors represented different periods, and overall, the prevalence rate increased rapidly between the ages of 0 and 10, whereas after 10, it rapidly decreased. However, it significantly increases in the 60–64 and 65–69 age groups, peaking around the age 75 (Fig. 3A). Notably, the prevalence decreased among individuals in the same age group compared with those in the past. We analyzed the changes in cohort-specific asthma prevalence across different periods. The line segment between every two triangles represented an age cohort (Fig. 3B and C). We found that people born after 2000 and those born before 1950 had an increased risk of asthma. The age distribution of each period was a function of age and period. Therefore, we

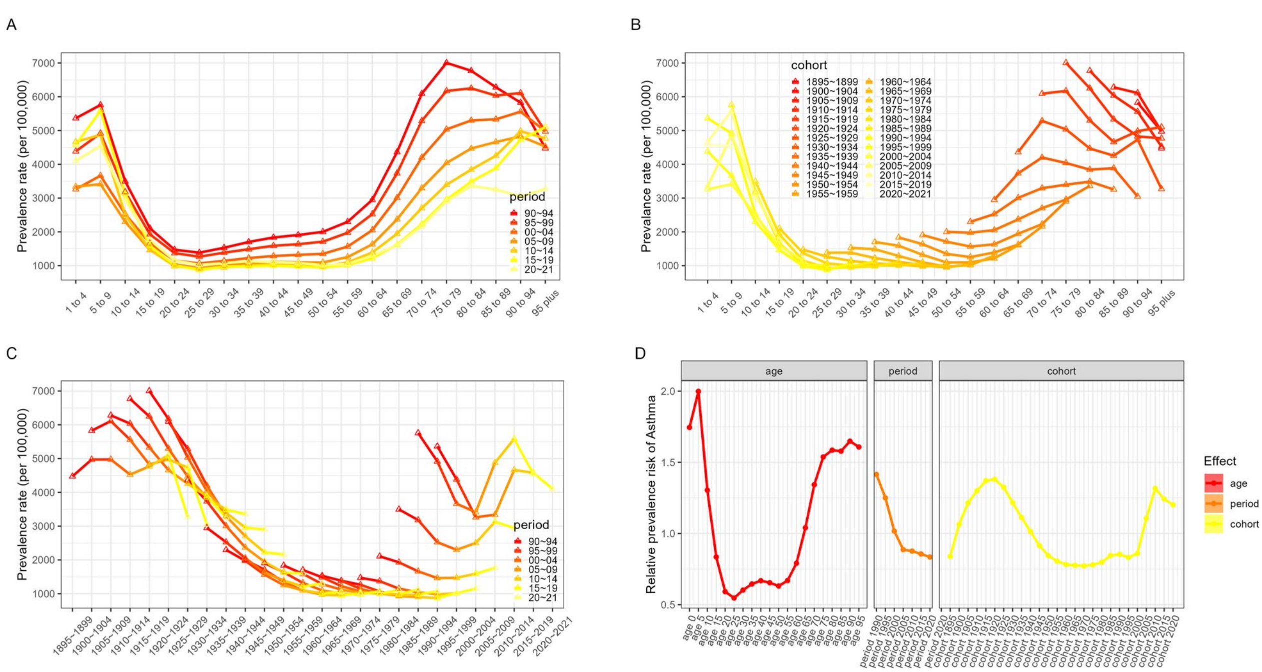

Fig. 3 Age-period-cohort (apc) model analysis of asthma prevalence in China. **A** Age-specific changes in prevalence. **B** Prevalence changes by cohort. **C** Baseline prevalence changes across different periods. **D** Diagram of age-period-cohort effect estimates. To account for multiple dimensions of influencing factors in disease progression, we used the apc model to decompose asthma prevalence into age, period, and cohort effects. This analysis helps reveal the true impact of asthma by representing each age group through different cohorts across various periods. The age distribution for each period is influenced by both age and period effects

used the apc model to adjust for two other factors and yield independent effects. The age component represented the relative disease risk for each age group compared with all other age groups. The period component indicated the independent effect of the current period after adjusting for the other two factors. The cohort component represented the cumulative effect of the three variables on disease risk. We found that there was a greater relative disease risk in the age groups under 15 and over 65. Moreover, the disease risk was lower than that in the past (Fig. 3D).

Risk factors

According to the Global Burden of Disease Study 2021 framework of risk factor classification, factors associated with asthma DALYs in China were categorized into four levels. There were three types of level one risk factors: metabolic risks, behavioral risks, and environmental/occupational risks. We analyzed the attributable risk factors for DALYs in China in 1990 and 2021 among different age groups (all ages, < 5 years, < 20 years, 20–54 years, 50–74 years, and > 75 years) (Fig. 4). We found that the burden attributable to metabolic risk (mainly obesity) continued to rise. The contribution of high body mass index (BMI) increased from 6.4% to 15% in the all-age group, and it was the most significant and rapidly changing factor in the < 20 years group. These findings suggest that interventions should focus on metabolic factors. In the all-age group, the overall impact of environmental and occupational risks (air pollution, occupational asthmagens) was relatively stable, while factors related to behavioral risk (such as smoking) increased slightly.

Discussion

Asthma is a common chronic noninfectious disease caused by a combination of complex and incompletely understood environmental and genetic interactions [14]. These factors influence both its severity and its responsiveness to treatment. On the basis of GBD 2021, asthma affects 298 million people around the world and approximately 19 people per 1000 people in China. It has a great impact on national economic and social development, and children and young people are the most commonly affected. In this study, we examined trends in the burden of asthma in China over the last 30 years. To our knowledge, this is the first analysis of the epidemiological trends of asthma in China using the joinpoint analysis combined with the apc model.

We found that asthma ASIR decreased by 30.6%, from 524.81 to 364.17 per 10,000 people in 2021, compared with 1990, and that age-standardized mortality decreased

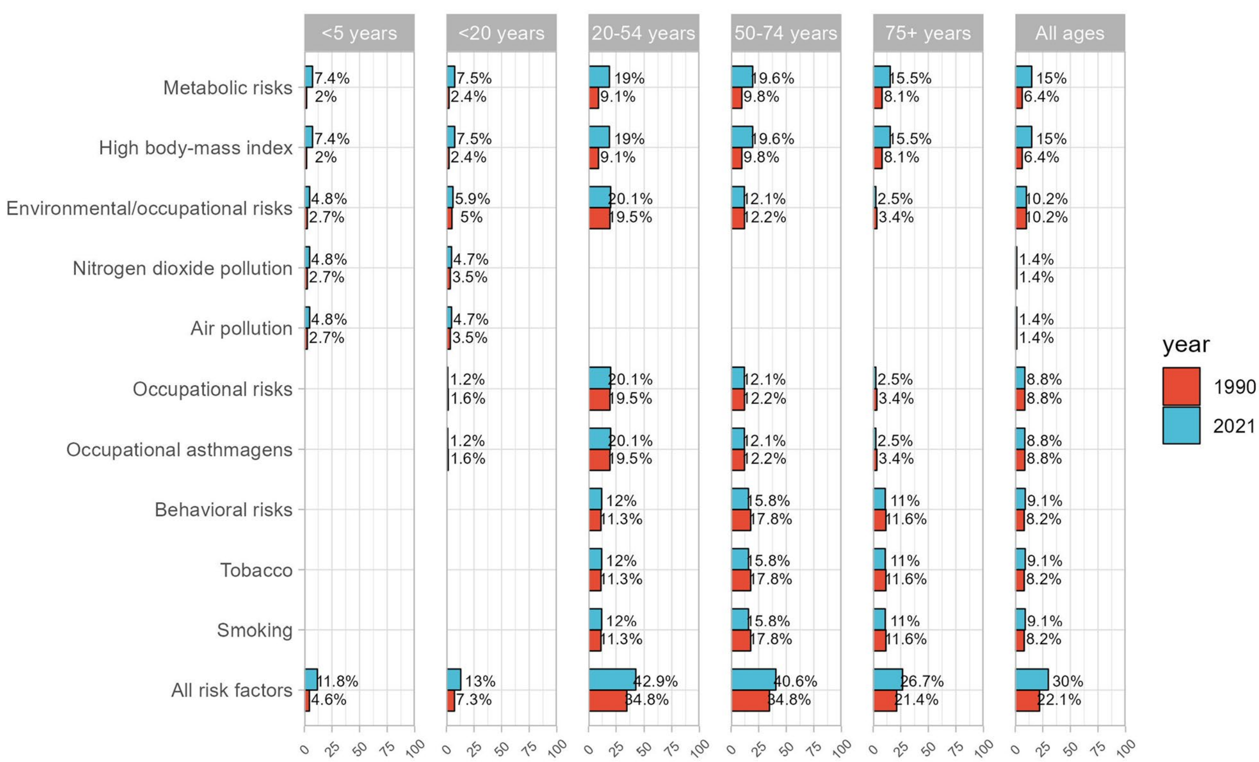

Fig. 4 Attributable risk factors for DALYs in China in 1990 and 2021 among different age groups

by 74.7%, compared with 1990. Compared with those in 1990, the DALYs, YLLs, and YLDs in 2021 decreased to varying degrees. This indicates an overall decline in the burden of asthma, including a reduced incidence, mortality, and disability associated with the disease. The ASPR of asthma patients decreased significantly at intervals ranging from 15 to 25 years; however, it increased significantly at intervals ranging from 65 to 75 years. This may be due to comorbidities, the use of additional medication for other diseases, and the psychosocial effects of aging in the older groups [14, 15]. Corticosteroids control asthma symptoms by modulating the immune system and alleviating inflammatory responses[16]. However, elderly patients experience a decline in pulmonary function and a weakened immune system, resulting in reduced sensitivity to corticosteroids [17]. Consequently, the management of asthma symptoms in the elderly population could be particularly challenging. Concurrently, the convergence of clinical features between asthma and chronic obstructive pulmonary disease (COPD) contributes to a substantial rate of misdiagnosis, especially among the elderly. This diagnostic confusion may be linked to more pronounced asthma severity, poorer adherence to pharmacotherapy, and a long-term of tobacco use in this demographic [18, 19]. In addition, asthma that starts before the age of 12 years is more likely to be due to heritable influences, whereas asthma onset after the age of 12 years is more likely to be due to environmental influences [20]. On the basis of these differences in underlying mechanisms, distinct age-related peaks in incidence are observed within each respective age group. With the aging population in China, the proportion of elderly individuals and late-onset asthma cases is expected to increase [21]. These age-specific characteristics and the increased prevalence of late-onset asthma pose significant challenges in managing and treating asthma effectively in the future.

Joinpoint analysis revealed that the incidence of asthma in China had fluctuated and decreased. The critical turning points were in 2005 and 2014. Prior to 2005, the incidence of asthma declined annually. However, after 2005, the incidence began to rise. This increase continued until approximately 2014, after which the rate of increase slowed and began to decline gradually. Subgroup analyses indicated that the incidence rate for males consistently exceeded that for females each year. The sex differences may be due to differences in genetics, sex hormone levels, tobacco use, BMI, and other factors [22–24]. After adjusting for collinear variables, the apc analysis indicated a decline in the relative risk of asthma over time. Additionally, the risk of asthma showed a U-shaped distribution across different age groups, with a similar curve observed in the birth cohort.

In 2021, the major predisposing factors for asthma-related DALYs included metabolic, behavioral, and environmental/occupational risks. In this study, we further observed that overweight or obesity-high-risk factors were ranked first with respect to the development of asthma in individuals aged < 20 years and in those aged > 50 years compared with those in 1990. Occupational asthmagens were more prevalent in the 20–54 age group, followed by behavioral risks (smoking) in patients aged > 50 years. Recent studies have highlighted a growing link between obesity and asthma, indicating that patients with both conditions might exhibit a different asthma phenotype than those with normal body weight. Specifically, asthma associated with obesity is frequently categorized as type 2-low asthma, which is characterized by a lack of significant type 2 inflammation (e.g., low levels of eosinophils and type 2 cytokines such as IL-4, IL-5, and IL-13) [20, 25]. In type 2-low asthma, the inflammatory process differs from that in type 2-high asthma. Instead of being driven by Th2 cells and associated cytokines, type 2-low asthma may involve other immune mechanisms and pathways that are not yet fully understood. The presence of obesity can complicate the asthma phenotype, potentially leading to different inflammatory profiles and impacting disease severity and treatment response. This evolving understanding emphasizes the need for tailored approaches to manage asthma in obese patients, considering their unique inflammatory characteristics and treatment requirements. Previous studies have shown that both active and passive smoking are independent risk factors for asthma onset, with smoking adversely affecting asthma control, treatment efficacy, and prognosis [26]. Furthermore, smoke exposure is associated with increased asthma mortality in the elderly [27]. Therefore, enhanced health management for smokers in China is essential, including increased health education and smoking cessation interventions to reduce asthma incidence and effects. Occupational exposure is a significant risk factor for adult-onset asthma. Occupational asthma can be induced through allergic reactions to specific substances in the workplace or exposure to inhalable irritants encountered during work activities [28]. According to estimates from the Global Burden of Disease (GBD) 2021 study, 8.8% of deaths attributable to asthma can be associated with occupational exposures. Prevention of occupational asthma may be enhanced by increasing health education for individuals working in relevant professions and improving industrial and occupational hygiene regulations.

GBD 2021 presents, for the first time, the estimates of health loss due to the first 2 years of the covonavirus disease 2019 (COVID-19) pandemic (2020 and 2021). In 2021, COVID-19 became the leading cause of all-age

DALYs, surpassing neonatal disorders, ischemic heart disease, and stroke. Other COVID-19 pandemic-related outcomes was the eighth leading cause of DALYs [8]. Notably, the GBD 2021 did not analyze how COVID-19 influenced the incidence and mortality of other diseases through direct causal relationship measurements. Instead, it reflected the pandemic's impact on other health issues via factors such as excess mortality, disruptions in healthcare services, and socioeconomic changes. In our study, Figs. 2 and 3 do not indicate a significant trend in the incidence or prevalence of asthma between 2020 and 2021. This observation may imply that the influence of COVID-19 on asthma incidence and related metrics in the general population is relatively limited. A multinational cohort study from South Korea, Japan, and the UK observed higher incidences of allergic diseases among moderate to severe COVID-19 patients. However, after receiving at least two doses of a COVID-19 vaccine, the risks of overall allergic disease and its subtypes, including asthma were no longer significantly higher than the non-infected controls [29]. This suggests that the lack of a significant impact on asthma incidence in China may be attributable to high COVID-19 vaccination rates, particularly among urban residents.

In conclusion, research on the disease burden of asthma in China has made substantial and comprehensive progress in recent years, leading to an overall improvement in the burden of asthma. Stricter air pollution controls have diminished exposure to asthma triggers. Enhanced healthcare systems and heightened public health awareness have improved disease management. Furthermore, urbanization and socioeconomic progress have fostered better living conditions and expanded access to medical resources. These changes underscore the efficacy of national policies on public health.

Our study has several limitations. First, the apc model and risk attribute analysis cannot establish causal relationships and are prone to bias. Second, this study did not compare asthma in China with that in other regions globally. Future research should address this gap to assess the comparative severity and burden of asthma in different populations. Third, incorporating provincial-level research data and obtaining more representative data from both developed and remote areas are essential for a comprehensive understanding of the impact of asthma. Future studies could improve predictive accuracy by utilizing long-term case registration data or conducting regular sampling surveys. Despite these limitations, our research offers valuable and updated insights into the burden of asthma and its risk factors in China.

Conclusion

The incidence and mortality rates of asthma in China notably decreased from 1990 to 2021. Despite the overall reduction, asthma remains a significant concern, particularly among adolescents and elderly individuals, who face greater relative risks. The primary contributors to asthma burden are metabolic risk factors, with obesity being a major factor. These findings highlight the importance of focusing on specific risk factors and tailoring public health strategies to address the needs of different age groups.

Abbreviations

GBD	Global Burden of Disease
YLDs	Years lost due to premature mortality
YLLs	Years of life lost
DALYs	Disability-adjusted life years
apc	Age-period-cohort
AAPC	Average annual percentage change
APC	Annual percent change
ASIR	Age-standardized incidence rate
ASMR	Age-standardized mortality rate
ASPR	Age-standardized prevalence rates
CODEm	Cause of death ensemble model
STGPR	Spatiotemporal Gaussian process regression
BMI	Body Mass Index
IL-4	Interleukin 4
IL-5	Interleukin 5
IL-13	Interleukin 13
95% UI	95% Uncertainty Interval
95% CI	95% Confidence Interval
COPD	Chronic obstructive pulmonary disease
COVID-19	Coronavirus disease 2019

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Author contributions

QZ and NL conceived this study. NL and YX performed the data analyses and wrote the manuscript. XX, ZD, and CS contributed to figure plotting and manuscript revision.

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Availability of data and materials

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

All the statistical analyses in our study were based on publicly available summary data. This study does not contain any studies with human or animal subjects performed by any of the authors, therefore, no ethical approval was needed.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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