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An analysis of the burden of respiratory tract cancers in global, China, the United States and India: findings based on the GBD 2021 database

Xinxin Liu[1†], Guoyu Wang[1,3†], Yafei Chen[2†], Siyi Ma[1], Bozhen Huang[1], Shanshan Song[1], Luyao Wang[1], Wanqing Wang[1] and Min Jiang[1*]

Abstract

Objective This study aimed to assess the burden of respiratory tract cancers in China, the United States, India, and worldwide from 1990 to 2021. Also, forecast the evolution of respiratory tract cancers deaths and DALYs burden during 2022 to 2050.

Study design An epidemiological analysis.

Methods Based on the GBD 2021 data, this article analyzed and discussed the trends in burden of respiratory tract cancers in China, the United States, India, and the world from 1990 to 2021. Additionally, the Bayesian Age-Period-Cohort (BAPC) model was used to forecast the evolution of respiratory tract cancers deaths and DALYs burden during 2022 to 2050.

Results The ASR-Deaths and ASR-DALYs for laryngeal and TBL cancers decreased globally. The burden of disease for TBL cancer increased in China and India (AAPC: 0.38 and 0.69), especially among Chinese women, while laryngeal cancer declined in India (AAPC: -0.69). In contrast, the burden of disease for both cancers declined substantially in the United States (-1.82 AAPC for laryngeal cancer and – 1.74 AAPC for TBL). A notable gender disparity existed in the burden of respiratory tumors, with males experienced a higher disease burden compared to females. In terms of age, the peak incidence of respiratory tract cancers predominantly occurred among individuals aged 65–74, indicating a clear tendency towards a higher prevalence among this age group. Population growth and ageing were primary factors influencing the mortality burden of larynx cancer, whereas epidemiological shifts in TBL cancer markedly impacted DALYs. The forecasted results for ASR-Deaths and ASR-DALYs worldwide from 2022 to 2050 indicated a decline in the burden of both larynx and TBL cancers. However, the deaths and DALYs of TBL cancer in China will show an upward trend, especially for females.

†Xinxin Liu, Guoyu Wang and Yafei Chen contributed equally as co-first authors.

*Correspondence:
Min Jiang
jiangmin545@bjsjth.cn

Full list of author information is available at the end of the article

Conclusions The disease burden of respiratory tract cancers is a global health issue that needs attention, and situations vary from country to country, requiring personalized measures. Global strategies must address aging populations and socioeconomic disparities to reduce inequities in high-burden regions.

Keywords Respiratory tract cancers, Disability-adjusted life-years, Mortality, Global epidemiology, Projection

Introduction

Respiratory tract cancer is one of the major challenges in global public health, and its high morbidity, mortality, and socioeconomic burden make it a central issue in cancer prevention and control. Respiratory tract cancer refers to malignant tumors occurring in the upper respiratory tract (nasal cavity, pharynx, larynx) to the lower respiratory tract (trachea, bronchus, lung), mainly including laryngeal cancer, tracheal cancer, bronchus cancer and lung cancer. Among them, tracheal, bronchus and lung (TBL) cancer is predominant, while laryngeal cancer is included in the broad category of respiratory cancers due to anatomical continuity and overlapping risk factors. According to the most recent data compiled by the International Cancer Center [1], TBL cancer represented the highest incidence of cancer worldwide in 2022, accounting for 12.4% of all new cancer cases. Simultaneously, TBL cancer had the highest mortality rate, accounting for 18.7% of all cancer-related deaths. TBL cancer, as the main type of respiratory tract cancer, has occupied the leading position in global cancer deaths for a long time, emphasizing its severe disease burden. As a key component of the upper respiratory tract, the larynx is directly involved in the composition of the breathing passages, and its lesions may spread downward to the trachea or bronchi. The main risk factors of laryngeal cancer highly overlap with those of lung cancer (e.g., smoking, air pollution, occupational exposure, HPV infection). In spite of laryngeal cancer has a low incidence rate (0.9%), it has a notable impact on the quality of life of patients due to the involvement of important physiological functions (such as vocalization and respiration). The study of the epidemiological characteristics and regional differences of these two types of cancer is crucial for optimizing global respiratory tract cancer prevention and control strategies.

The Global Burden of Disease (GBD) provided a detailed global burden of disease, injury and risk factor studies that compare conditions by age group, gender, countries, regions, and time, providing information on the major causes of deaths and DALYs due to disease. Although previous studies have shed light on some of the risk mechanisms for respiratory tract cancer, heterogeneity at the global level remains insufficiently elucidated [2, 3]. For example, early screening and advances in targeted therapies in high-income countries like the United States have notably improved patient survival (5-year survival of approximately 22%), whereas low- and middle-income countries (e.g., China and India) have less than 15% survival due to diagnostic delays and insufficient treatment accessibility. Therefore, epidemiological data from the world, China, the United States, and India were selected for this study not only because of their large populations (China and India account for 36% of the world's population) and varied disease profiles (e.g., the United States has successful tobacco control cases and India has unique risk exposures [4]), but also because of the varied health systems in these countries and regions, which provide an opportunity to study the 'social determinants-prevention/control measures-disease outcomes' associations provide a natural contrast to inform the development of precise, localized epidemiological strategies for respiratory cancers. Based on existing evidence of increasing respiratory tract cancer burden and changing demographic patterns, we hypothesized that: (1) The burden of respiratory tract cancers (both larynx and TBL cancers) would show significant temporal and geographic variations from 1990 to 2021, with different patterns between developed and developing countries; (2) Population aging and growth would be the primary drivers of changes in disease burden, but their relative contributions would vary by country development level; (3) Gender disparities in disease burden would be substantial and possibly widening over time due to historical differences in risk factor exposure, particularly smoking habits; (4) The future trends (2022–2050) of disease burden would differ significantly among countries due to their distinct stages of epidemiological transition and demographic changes. In this regard, this study aims to systematically analyze the differences in disease burden between TBL and laryngeal cancers by integrating epidemiological data from around the world, China, the United States, and India, focusing on deaths and DALYs for respiratory cancer and distinguishing subgroups by gender and age in order to better visualize more detailed differences in the burden of disease by age and gender, while focusing analysis on specific age groups. In addition, we projected mortality and DALYs for respiratory cancer in 2050 by adjusting for the age factor so that differences in age distribution between countries did not affect the results and exploring the scientific basis for the optimization of prevention and control strategies.

Methods

The GBD 2021 study offers extensive estimates of risk exposure and associated health losses from 1990 to 2021 across 204 countries and territories worldwide. Following the guidelines outlined in the GBD 2021 report (http://ghdx.healthdata.org/gbd-results-tool), we acquired data on the incidence and mortality of respiratory tract cancers, specifically TBL cancer and larynx cancer, including age-standardized rates (ASR). For ASR calculation, we organized data into 5-year age groups (0–4, 5–9,..., 95 + years) and applied direct standardization using the GBD 2019 world standard population as reference. To conduct a more granular analysis of respiratory tract cancers distribution by gender and age, we also gathered pertinent demographic information. Furthermore, we selected global data alongside data from the three most populous nations—China, the United States, and India—to examine respiratory tract cancers trends from 1990 to 2021.

We employed the Joinpoint regression model, a segmented regression technique that capitalizes on the temporal characteristics of disease distribution. This model partitions the study period into distinct intervals using a series of joinpoints, subsequently fitting and optimizing the trend within each interval. This approach facilitates a more nuanced evaluation of interval-specific disease changes on a global temporal scale. In our study, we utilized the Joinpoint regression model to identify inflection points in disease prevalence trends. We computed the Annual Percent Change (APC) in prevalence rates between these inflection points, as well as the Average Annual Percent Change (AAPC) for the entire age cohort. The AAPC, which represents the weighted average of the APCs across segmented intervals, encapsulates the overall trend in disease prevalence from 1990 to 2021.

Let b_i as the slope coefficient for the i^{th} segment with i indexing the segments in the desired range of years, and w_i as the length of each segment in the range of years. Then:

$$\mathrm{APC_i} = \{\exp(\mathrm{b_i}) - 1\} \times 100$$

$$\mathrm{AAPC} = \left\{ \left(\sum w_i b_i \Big/ \sum w_i \right) - 1 \right\} \times 100$$

We conducted an in-depth analysis of TBL cancer and larynx cancer trends using ASR for deaths and Disability-Adjusted Life Years (DALYs). We applied an Age-Period-Cohort (APC) interaction analysis, which allowed us to simultaneously account for the effects of age, time period, and birth cohort on the burden of different respiratory tract cancers types. This analytical approach provided enhanced insights into the differential impacts of TBL cancer and larynx cancer on disease burden over time, enabling us to ascertain their relative contributions to overall changes in disease burden.

To gain deeper insights into how various demographic and disease characteristics contribute to the overall disease burden, we performed Age-Period-Cohort (APC) analysis. In the APC model, we used 1992–1996 as the reference period, age group 65–69 years as the reference age group (which showed the highest standardized rate during the reference period), and the corresponding birth cohort (1927–1931) as the reference cohort. This reference selection strategy enabled us to quantify the relative contributions of age, period, and cohort effects to the temporal trends in respiratory tract cancers. After setting reference groups, we decomposed the burden into factors such as population age, population size, and epidemiologic change. This decomposition allowed for a more precise assessment of the impact of age structure, demographic shifts, and epidemiologic factors on disease burden. Additionally, we provided a detailed breakdown of epidemiologic changes to examine the impact of different respiratory tract cancers types on changes in disease burden.

Health Inequality Analysis (HIA) is a statistical methodology used to evaluate disparities in health status across different populations. It focuses on elucidating the relationships between variables such as socioeconomic status, geographic location, gender, and age, and their effects on health outcomes. In this study, we utilized two key indicators: the Slope Inequality Index (SII), an absolute health inequity indicator, and the Concentration Index (CIX), a relative health inequity indicator. These metrics allowed us to analyze the distribution and trends of health inequalities in respiratory tract cancers from 1990 to 2021, effectively quantifying the influence of socioeconomic factors on health status.

To forecast the respiratory tract cancers burden from 2022 to 2050, both globally and for China, India, and the United States, we applied Bayesian Age-Period-Cohort (BAPC) modeling. This modeling approach not only addresses noise and uncertainty in the sample more effectively but also leverages known information outside the sample to provide more reliable predictions [5].

All data processing in this study was conducted using R (V 4.3.0). For the joinpoint regression analysis, we used R to call the National Cancer Institute's Joinpoint Regression Program (V 4.9.1) through the command-line interface, which was integrated into our analysis workflow.

Results

Global burden of respiratory tract cancers

The global impact of respiratory tract cancers in 2021 demonstrated substantial variation across countries, as reflected in national data on disability-adjusted life years (DALYs) and deaths. As illustrated in Fig. 1A, the absolute

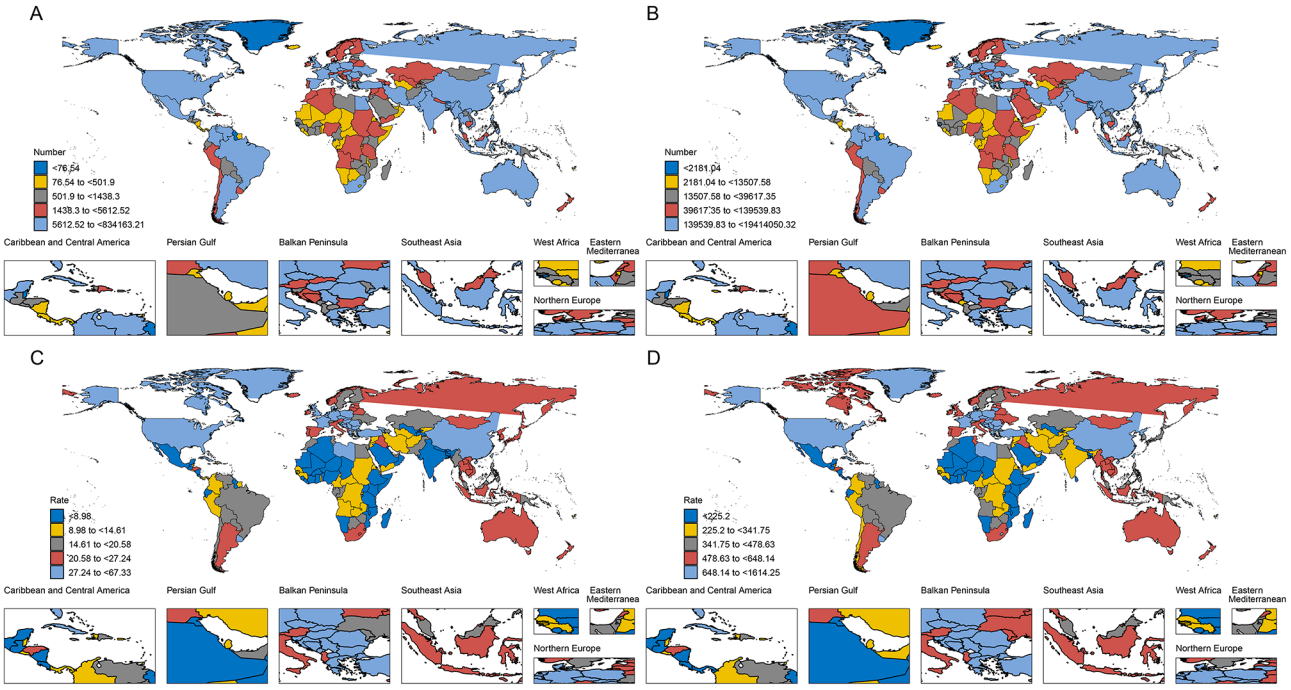

Fig. 1 Global Distribution of Respiratory Tract Cancers Burden in 2021. (**A**) Deaths-Number of Respiratory Tract Cancers (**B**) DALYs-Number of Respiratory Tract Cancers (**C**) Deaths-ASR of Respiratory Tract Cancers (**D**) DALYs-ASR of Respiratory Tract Cancers

number of deaths due to respiratory tract cancers showed remarkable geographical disparities. China had the highest mortality burden, with 834 thousand deaths (95% CI: 668 to 1,013). This was followed by the United States, with 180 thousand deaths (95%CI: 165 to 190), and India was reported 103 thousand deaths (95%CI: 86 to 119). DALYs further reflected the impact of respiratory tract cancers on the quality of life and productivity of patients in these countries, depicted in Fig. 1B. Consistent with the number of deaths, China topped the list for DALYs at 19 million (95% CI: 15 to 24). The United States was second with 3.8 million DALYs (95% CI: 3.5 to 3.9). India followed with 2.9 million DALYs (95% CI: 2.4 to 3.3).

Age standardization rate (ASR) can eliminate the influence of different age structures on results and enable more reliable cross-country comparisons. We further analyzed the ASR of deaths and DALYs, and the ranking was consistent with the above. The Deaths-ASR in China, the United States and India were 39.9 deaths per 100,000 people (95% CI: 32.1 to 48.2) and 29.7 per 100,000 people (95% CI: 27.4 to 31.2), 8.6 per 100,000 people (95% CI: 7.2 to 9.9), respectively. DALYs reflect the harm caused by premature deaths and DALYs from respiratory tumors, as shown in the Fig. 1D. China, the United States and India led the list with 901.0 DALYs (95% CI: 721.2 to 1097.4), 650.0 DALYs (95% CI: 610.6 to 678.0) and 226.5 DALYs (95% CI: 188.8 to 262.0).

Distribution of respiratory tract cancers subtypes

In the GBD database, respiratory tract cancers were categorized into larynx cancer and TBL cancer. According to data from 1990 (Fig. 2A), larynx cancer accounted for only 7.4%, while TBL cancer accounted for 92.6% of deaths worldwide. In the same year, the distribution of DALYs due to respiratory tract tumors was similar (Fig. 2B), larynx cancer was 8.0% and TBL cancer was 92.0%. By 2021, the difference in the distribution of larynx cancer and TBL cancer had widened further (Fig. 2C). Larynx cancer decreased to 5.5% and TBL cancer deaths increased to 94.5%. The distribution of DALYs in 2021 showed the same trend (Fig. 2D), with larynx cancer decreased to 6.3%, TBL cancer increasing to 93.7%.

In addition, we analyzed the proportional impact of different respiratory tract tumors on DALYs and deaths in China, India, and the United States in 1990 and 2021. In China, the deaths rate of larynx cancer dropped from 7.7 to 2.4%, and the DALYs from 4.5 to 2.5%. In contrast, the deaths of TBL cancer in China increased from 92.3% in 1990 to 97.6%, and the DALYs increased from 95.5 to 97.5%. The situation in the United States was similar to that in China. Deaths of larynx cancer in the United States decreased from 10.3 to 2.6%, and TBL cancer increased from 89.7 to 97.4%. However, the trend was reversed for DALYs, with larynx cancer increased from 2.8 to 3.0% and TBL cancer decreased from 97.2 to 97.0%. In India, the change over the 31-year period was more

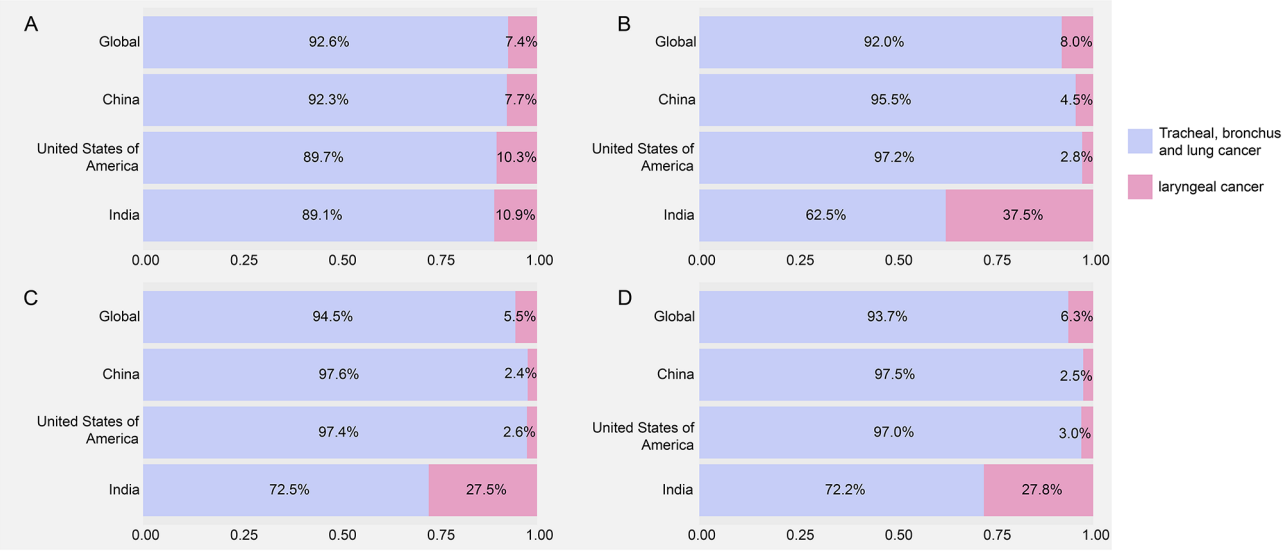

Fig. 2 Distribution of Different DM Types (**A**) Distribution of Respiratory Tract Cancers Deaths in 1990 (**B**) Distribution of Respiratory Tract Cancers DALYs in 1990 (**C**) Distribution of Respiratory Tract Cancers Deaths in 2021 (**D**) Distribution of Respiratory Tract Cancers DALYs in 2021

Table 1 The AAPC of DALYs and deaths due to tracheal, bronchus, and lung cancer, larynx cancer in Global, China, India, and the United States from 1990 to 2021

	Case	DALYs		Deaths	
		AAPC (95%CI)	*P* value	AAPC (95%CI)	*P* value
Global	Larynx cancer	-1.16(-1.65 to -1.56)	< 0.001	-1.47(-1.51 to -1.42)	< 0.001
	Tracheal, bronchus, and lung cancer	-0.86(-0.04 to -0.67)	< 0.001	-0.54(-0.7 to -0.37)	< 0.001
China	Larynx cancer	-1.88(-2.13 to -1.63)	< 0.001	-1.73(-1.96 to -1.49)	< 0.001
	Tracheal, bronchus, and lung cancer	0.06(-0.13 to 0.26)	0.535	0.38(0.13 to 0.63)	0.003
India	Larynx cancer	-0.85(-1.1 to -0.61)	< 0.001	-0.69(-0.93 to -0.45)	< 0.001
	Tracheal, bronchus, and lung cancer	0.57(0.38 to 0.75)	< 0.001	0.69(0.47 to 0.91)	< 0.001
United State of America	Larynx cancer	-1.99(-2.13 to -1.84)	< 0.001	-1.82(-2.03 to -1.61)	< 0.001
	Tracheal, bronchus, and lung cancer	-2.21(-2.36 to -2.06)	< 0.001	-1.74(-1.93 to -1.55)	< 0.001

pronounced, with larynx cancer increased from 10.9 to 27.5% and TBL cancer deaths decreased from 89.1 to 72.5%. In terms of DALYs, larynx cancer decreased from 37.5 to 27.8%, and TBL cancer increased from 62.5 to 72.2%.

Joinpoint regression analysis of respiratory tract cancers trends

To understand the changing trends in different stages and identify turning points, we conducted a joinpoint regression analysis on larynx cancer and TBL cancer (Table 1; Fig. 3). The ASR-Deaths of larynx cancer exhibited a significant downward trend globally (AAPC=-1.47, 95% UI: -1.51 to -1.42, $p < 0.001$). Since 1990, particularly between 1994 and 2007, when the annual percentage change (APC) was −2.17. A similar pattern was observed for ASR-DALYs related to larynx cancer, which also demonstrated a downward trajectory (AAPC = -1.61, 95% UI: -1.65 to -1.56, $p < 0.001$), with the most pronounced decline occurring during the same period from 1994 to 2007 (APC = -2.35). In contrast, while there is an overall decreasing trend in ASR-Deaths rates for TBL cancer (AAPC = -0.54, 95% UI: -0.70 to -0.37, $p < 0.001$), there were periods of insignificant increases noted between 1990 and 1995 and again from 1998 to 2004 (APC: 0.01 and 0.04 respectively). Correspondingly, ASR-DALYs showed a steady decline over time (AAPC = -0.86, 95% UI: -0.04 to -0.67, $p < 0.001$).

A focus on specific countries revealed that the overall trend in China was declined as well, with the deaths of larynx cancer continuing to improve significantly (AAPC =-1.73, 95% UI: -1.96 to -1.49, $p = 0.003$), particularly marked by a substantial decrease from 1994 to 2007 (APC = -3.58). The corresponding ASR-DALYs also reflected this downward trend with an AAPC of -1.88 (95% UI: -2.13 to -1.63, $p < 0.001$). In contrast, TBL cancer in China is challenging, with a slight increase in both deaths (AAPC = 0.38) and DALYs (AAPC = 0.06, 95% UI: -0.13 to 0.26, $p = 0.535$). Even a rapid increased between 1997 and 2004 (APC = 2.23 and 1.59, respectively). India experienced the most stable decline in ASR-Deaths (AAPC=-0.69, 95% UI: -0.93 to -0.45, $p < 0.001$). However,

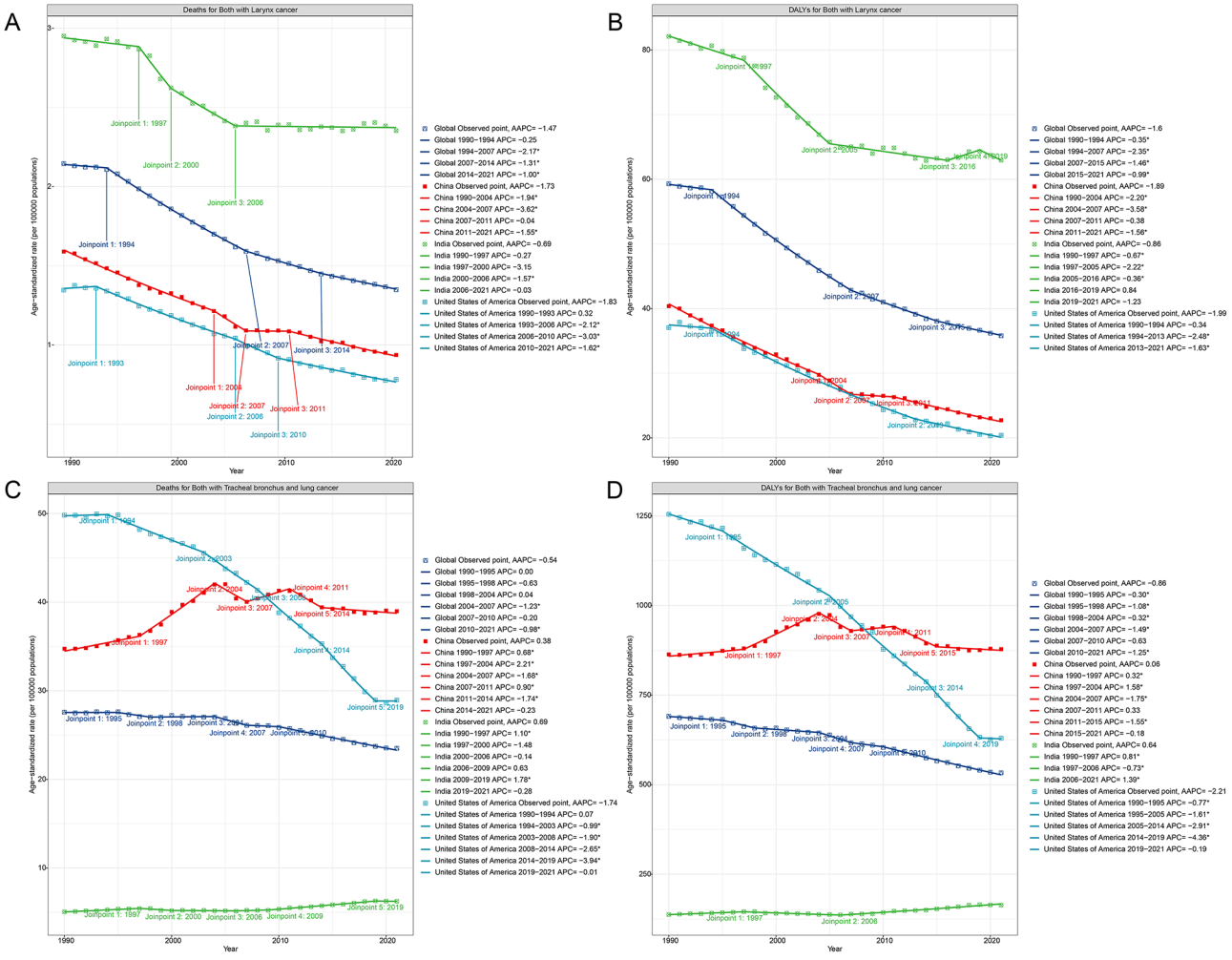

Fig. 3 Joinpoint Regression Analysis of Respiratory Tract Cancers Trends. (**A**) ASR-Deaths in larynx cancer (**B**) ASR-DALYs in larynx cancer (**C**) ASR-Deaths in TBL cancer (**D**) ASR-DALYs in TBL cancer

it saw a notable period of rapid decline between 1997 and 2000 where APC was recorded at -3.16. The corresponding ASR-DALYs also decreased slowly (AAPC=-0.85, 95% UI: -1.1 to -0.61, $p < 0.001$), and experienced an insignificant increase from 2016 to 2019 (APC = 0.79). At the same time, the trend of TBL cancer in India was not optimistic, and ASR-Deaths showed a relatively gradual increase (AAPC = 0.69), with segmental fluctuations. The corresponding ASR-DALYs also increased slowly (AAPC = 0.57, 95% UI: 0.38 to 0.75, $p < 0.001$). The trend of deaths from larynx cancer decreased most rapidly in the United States (AAPC=-1.82). Although there was no significant increase from 1990 to 1993 (APC = 0.35), there was a relatively rapid decline after 1993. The corresponding ASR-DALYs also decreased rapidly (AAPC=-1.99, 95% UI: -2.13 to -1.84, $p < 0.001$). Although the decrease from 1990 to 1994 was not significant (APC=-0.32), the subsequent periods showed a rapid and obvious downward trend. The United States also made significant progress in TBL cancer management. ASR-Deaths and ASR-DALYs decreased significantly (AAPC: -1.74 and – 2.21, respectively).

Age and gender distribution of respiratory tract cancers burden

A comprehensive analysis of the respiratory tract cancers burden by age group and gender could help us to better understand the current epidemiological situation. As shown in Fig. 4, the global burden of respiratory tract cancers showed a clear gender difference, with males had a higher disease burden than females. The burden associated with larynx cancer and TBL cancer demonstrated an initial increase followed by a decrease as age advances, reflecting a clear age-related trend. Deaths and DALYs attributable to larynx cancer reached a peak in the 60–69 and 55–64 years age group, particularly among older males who bore a noticeable disease burden. For females, the burden of deaths was less severe, the trend was more

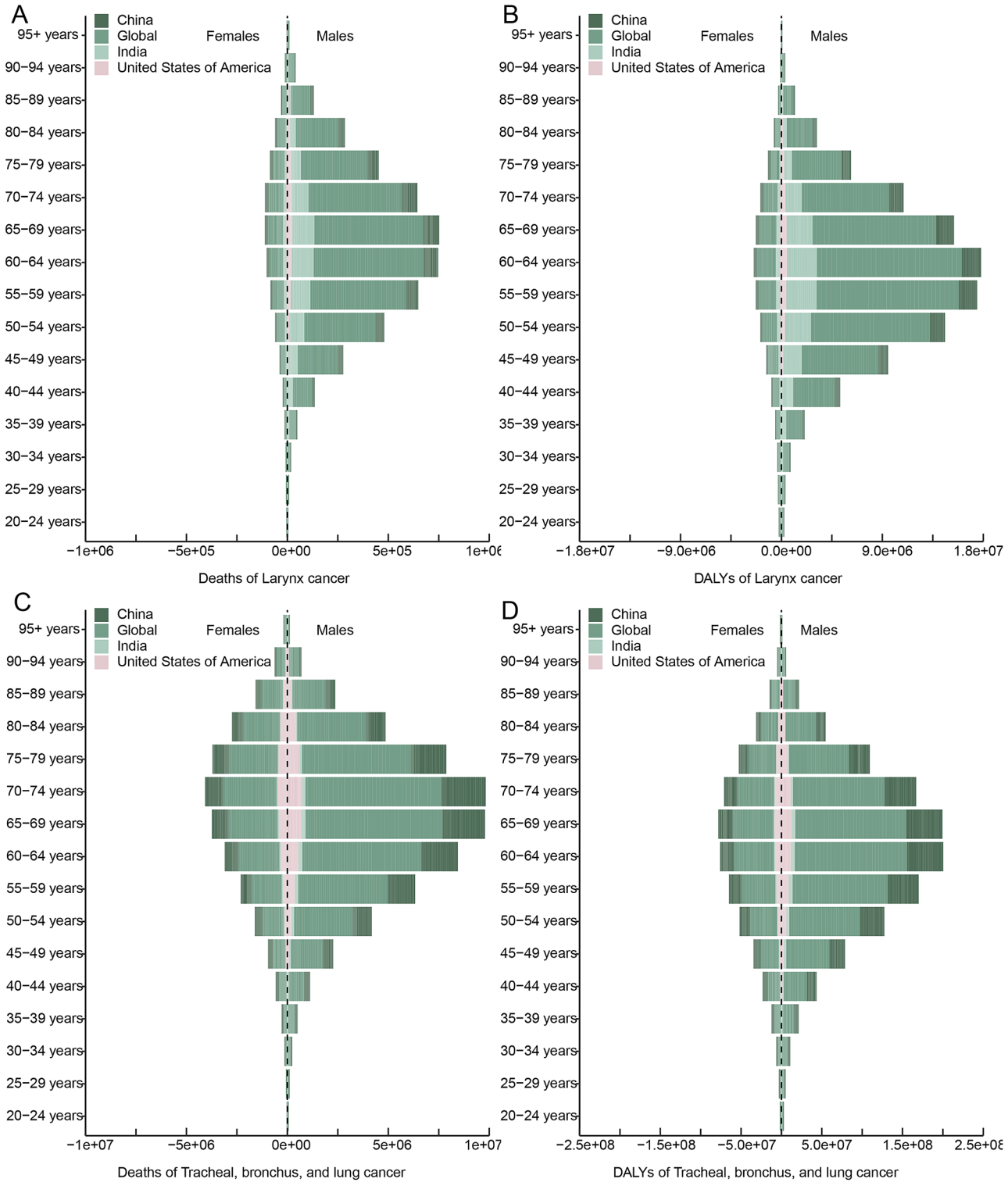

Fig. 4 Distribution of deaths due to larynx cancer and TBL cancer (stratified by gender and age). (**A**) Deaths caused by larynx cancer (**B**) DALYs caused by larynx cancer (**C**) Deaths caused by TBL cancer (**D**) DALYs caused by TBL cancer

gradual with age, and the peak age was later, at 65 to 69 age group. The corresponding DALYs burden reached a peak at the ages between 60 and 64. The burden of disease for TBL cancer showed a similar sex-related pattern, although there were still large differences between males and females, but not as pronounced as for larynx cancer. The deaths burden of males reached a peak in the 65–74 years age group, and the peak of DALYs at 60–69. For females, the burden peaked later than for males, with deaths peaking in the 70–74 years age group and DALYs peaking in the 65–69 years age group. Males had a greater burden of disease than females, especially in old age.

On a country-by-country basis, the trend in disease burden was similar in China, the United States, and India. It was characterized by an initial increase followed by a subsequent decrease with advancing age. China had a much greater burden of disease than India and the United States. In terms of the larynx cancer deaths burden in three countries, the peak for males occurred around 65–69 years old, while the peak for females in China and the United States occurred later, appearing at 70–74 years old. The peak burden of TBL cancer showed no gender differences, and was concentrated in countries between 65 and 74 years of age. The corresponding DALYs burden also reflected the obvious age tendency, with the peak for larynx cancer in males was concentrated in the 55–64 age group, as well the cases for females. The peak of lung cancer in all three countries was concentrated in the 55–69 age group, which was about the same.

Age-period-cohort analysis

For the APC analysis, we used 1992–1996 as the reference period, age group 65–69 years (which showed the highest standardized rate: 11.03 per 100,000, 95% CI: 10.35–11.75) as the reference age group, and the corresponding birth cohort (1927–1931) as the reference cohort.

Age-cohort analyses revealed trends in disease deaths cohort age. Compared with the reference age group during the reference period, age-specific patterns demonstrated distinct risk gradients: the younger age groups showed progressively lower rates (ages 55–59: 6.59 per 100,000; ages 45–49: 2.05 per 100,000), while older age groups showed slightly higher risks (ages 70–74: 12.14 per 100,000; ages 75–79: 12.30 per 100,000). The deaths rate of larynx cancer generally declined worldwide and in China as the cohort age increased. This decline was most pronounced in China, where the rate decreased from 13.02 (95% CI: 10.69–15.70) in the reference period to 7.31 (95% CI: 5.42–8.77) in 2012–2016. The deaths rate in the United States fluctuated in the age group over 85 years, increasing from 8.64 (95% CI: 7.28–9.29) to 9.05 (95% CI: 8.06–9.56) in the earliest birth cohort in the earliest birth cohort in the age group over 95 years. India, on the other hand, showed a fluctuating death rate in the age group over 80, ranging from 16.54 (95% CI: 13.11–20.14) to 17.78 (95% CI: 13.49–22.58). Correspondingly, DALYs decreased globally across birth cohorts, with the steepest decline observed in the 65–69 age group from 277.12 (95% CI: 260.12-295.17) to 188.38 (95% CI: 177.20-200.15) per 100,000 (Fig. 5A).

Age-period analyses indicated that globally, as well as in China and the United States, Deaths-ASR for larynx cancer exhibited an increase with advancing age,

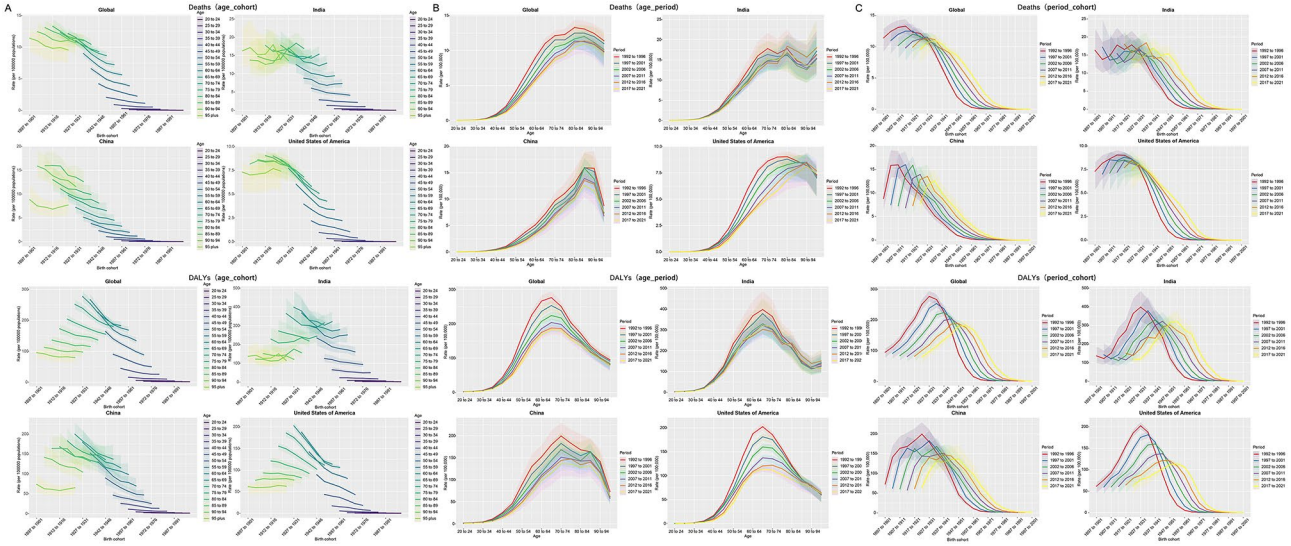

Fig. 5 The APC analyzes larynx cancer outcomes in deaths and DALYs. (**A**) Age-cohort analysis (**B**) Age-period analysis (**C**) Period-cohort analysis. DALYs, disability-adjusted life-years

followed by a decline, resulting in an arched distribution. During the reference period, the global age-specific pattern showed a clear gradient, with rates increasing from 0.91 per 100,000 (95% CI: 0.84–0.98) at ages 40–44 to a peak of 11.03 per 100,000 (95% CI: 10.35–11.75) at ages 65–69, before declining to 7.32 per 100,000 (95% CI: 5.37–8.27) in the oldest age group. China showed a more dramatic pattern, with rates rising from 0.53 per 100,000 (95% CI: 0.43–0.63) at ages 40–44 to 15.96 per 100,000 (95% CI: 13.45–18.91) at ages 85–89. India showed a similar but more volatile pattern, with a small fluctuation after age 75, fluctuating between 16.02 (95% CI: 13.01–19.53) and 17.81 (95% CI: 14.01–21.70) per 100,000. The peaks for global data, as well as for India and the United States, occurred in the period of 1992–1996, while China's peak was observed between 2002 and 2006, reaching 531.42 (95% CI: 470.88-585.34) per 100,000. Regarding DALYs-ASR, the trends of global and Chinese displayed a clear arch pattern with peaks occurring in the 65–69 and 70–74 age groups respectively during 1992 to 1996. The global peak reached 277.12 (95% CI: 260.12-295.17) DALYs per 100,000, while China's peak was substantially higher at 4768.4 (95% CI: 4256.27-5322.04). In contrast, in the United States, DALYs-ASR increased steadily with age from 520.59 (95% CI: 507.13-534.33) at ages 50–54 to 7458.79 (95% CI: 7092.02-7691.54) at ages 70–74, before showing a slight decline among older cohorts. India demonstrated persistent volatility after a sustained rise, with values ranging from 198.41 (95% CI: 172.24-229.02) to 717.12 (95% CI: 608.93-828.07) per 100,000 (Fig. 5B).

Period-cohort analyses revealed that the deaths due to larynx cancers declined globally and within individual countries over time as cohorts progressed. For larynx cancer, compared to the reference cohort (1927–1931), the death rates declined globally and within individual countries as cohorts progressed. Specifically, the global rate fell from 11.03 (95% CI: 10.35–11.75) to 7.23 (95% CI: 6.74–7.77) per 100,000 in the latest cohort. In the same cohort, the Deaths-ASR for larynx cancers increased over time. Most notably in the reference cohort (1927–1931), the rates rose from 7.73 (95% CI: 7.45–7.97) to 11.38 (95% CI: 9.97–12.32). Notably around 1987–1991, change curves across several periods began to converge. During this convergence period, the rates across different cohorts ranged from 8.12 (95% CI: 7.69–8.55) to 11.26 (95% CI: 9.96–12.08) per 100,000. For DALYs-ASR, the temporal pattern was more complex. During the same period, the variation in DALYs-ASR exhibited an arching trend, corresponding to cohort progression. The global DALYs-ASR in the reference cohort showed a distinct pattern, with values peaking at 277.12 (95% CI: 260.12-295.17) per 100,000. In the same cohort, the DALYs-ASR associated with different time periods reversed around 1947–1956. Before this reversal point, DALYs-ASR decreased from 251.54 (95% CI: 234.12-266.56) to 192.14 (95% CI: 180.48-203.79) per 100,000. After the reversal, it increased to 238.99 (95% CI: 224.35-252.48) per 100,000 beforeeventually converging to 0 (Fig. 5C).

The TBL cancer analysis revealed distinct patterns. The deaths rate of TBL cancer, measured by ASR, showed a strong age gradient, increasing from 8.62 (95% CI: 8.13–9.14) per 100,000 at ages 40–44 to a peak of 228.72 (95% CI: 209.03-240.65) at ages 80–84, before declining in the very elderly population. Overall, the Deaths-ASR initially increased with cohort progression, reaching a maximum of 277.77 (95% CI: 239.14-297.57) per 100,000, then decreased rapidly and finally stabilized. For DALYs-ASR, the pre-growth period was characterized by a steady increase from 415.34 (95% CI: 391.69-440.41) to 783.32 (95% CI: 747.28-823.01) per 100,000, followed by a noticeable trend reversal, then decreased rapidly and finally stabilized. On the other hand, DALYs-ASR had a similar trend with the cohort progression, but the pre-growth period was longer and it had experienced a noticeable trend reversal. When analyzing changes within the same age group in relation to the birth cohort, China demonstrated remarkable stability, with variations typically within 15% of baseline values. In contrast, global patterns showed fluctuations of up to 40% between consecutive cohorts. In the United States, there was a distinct linear decline observed in individuals aged 25–74, with rates decreasing consistently by approximately 2.5% per cohort (Fig. 6A).

In terms of age outcomes, global and national TBL Deaths-ASR increased with age and decreased in older age groups. For the global population, rates increased from 37.61 (95% CI: 35.82–39.51) per 100,000 at ages 50–54 to peak at 228.72 (95% CI: 209.03-240.65) per 100,000 in the 80–84 age group. The peak occurred at different age groups, with the United States showing a progressive delay in peak age across cohorts, from 368.52 (95% CI: 350.5-379.8) per 100,000 at ages 70–74 in early cohorts to 419.99 (95% CI: 367.44-446.51) per 100,000 at ages 80–84 in later cohorts. Meanwhile, with the peak in the United States gradually occurred later as the birth cohort is delayed, while global, India, and China were concentrated in the 85–94 age group, with peak values of 277.77 (95% CI: 239.14-297.57), 48.78 (95% CI: 40.66–55.14), and 541.79 (95% CI: 467.49-623.41) per 100,000, respectively. DALYs-ASR showed an arch trend of rightward center of gravity. In the global context, the burden increased from 1445.7 (95% CI: 1376.72-1518.18) DALYs per 100,000 at ages 50–54 to a maximum of 3909.35 (95% CI: 3748.23-4063.14) at ages 70–74. In the United States, the age group under 74 years old showed consistent declines across birth cohorts, with the most pronounced decrease observed in the 65–69 age group from 7269.59 (95% CI: 7016.64-7459.3) to 4309.05 (95%

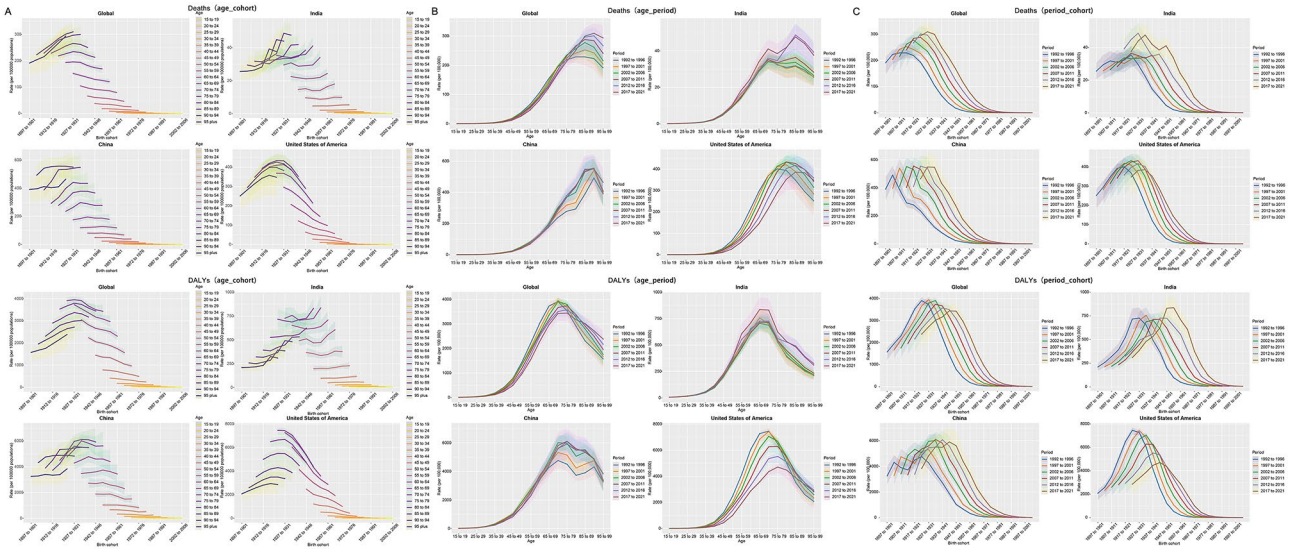

Fig. 6 The APC analyzes TBL cancer outcomes in deaths and DALYs. (**A**) Age-cohort analysis (**B**) Age-period analysis (**C**) Period-cohort analysis

CI: 4098.5-4443.86) DALYs per 100,000. Globally, after a period of volatility, the age group over 85 years old showed a downward trend, declining from 2308.15 (95% CI: 2018.23-2460.31) to 1954.92 (95% CI: 1633.23-2115.7) DALYs per 100,000. India and China revealed little fluctuation with birth cohort in most age groups (Fig. 6B).

The period-cohort analysis showed that, except for India, there was a slight increase followed by a rapid decline in TBL cancer deaths as the birth cohort progressed during the same timeframe. This pattern was most evident in China, where rates initially increased by 23.4% before declining by 45.6% in subsequent cohorts. India experienced a period of volatility and gradually declined, with rates fluctuating between 29.55 (95% CI: 25.28–34.1) and 35.42 (95% CI: 30.08–40.92) per 100,000 before settling into a declining trend. For the same cohort, global and national Deaths-ASR of TBL cancer increased over time, started with the 1922–1937 birth cohort, which showed an increase from 193.19 (95% CI: 185.22-200.75) to 255.99 (95% CI: 230.93-270.22) per 100,000. The DALYs-ASR temporal pattern showed marked regional variations. Globally, the arch-shaped distribution peaked at 3729.17 (95% CI: 3583.6-3885.6) DALYs per 100,000 in the reference period, before declining to 2642.17 (95% CI: 2160.69-2911.86) DALYs per 100,000. For the same birth cohort, both the world and countries experienced a reversal from a decrease in DALYs-ASR to an increase over time, with the inflection point occurring around 1947–1956, after which rates increased by an average of 2.3% annually (Fig. 6C).

Decomposition analysis

To investigate the effects of population ageing, population growth, and epidemiological changes on respiratory tract cancers-related deaths and DALYs from 1990 to 2021, we conducted a quantitative decomposition analysis (Fig. 7A-B). The results indicated that between 1990 and 2021, respiratory tract cancers-related deaths increased by approximately 968 thousand cases. Population growth emerged as the primary contributor to this increase, accounting for 88.77%, while population ageing contributed an addition of 443 thousand cases (45.73%). Changes in the epidemiology of TBL cancer reduced deaths by 29.30%, while trends in larynx cancer reduced deaths by 5.21%. Global DALYs due to respiratory tract cancers increased by 19 million, and the impact of population growth was very remarkable, accounting for 114.05% of the increase. Different from death, the epidemiological changes of TBL cancer had a more obvious effect, reducing DALYs by 55.46%, while population ageing factors increased DALYs by 49.45%.

Specific to the country, population ageing was the main cause of respiratory tract cancers Deaths and DALYs burden increase in China, accounting for 56.27% and 57.24%, respectively. The role of epidemiological changes was not obvious. In contrast, changes in the epidemiology of TBL cancer had a remarkable impact on the burden of deaths and DALYs in the United States (Fig. 7E-F). In terms of deaths, ageing and population growth had a large negative impact in the United States, accounting for 273.82% and 330.68%, respectively, and changes in the epidemiology of TBL cancer had remarkably reduced them. However, for DALYs, population growth and ageing were conducive to reduce the DALYs burden, and the prevalence of TBL cancer had noticeably increased the DALYs burden. The pattern was different in India, where population growth was the main factor to increase the burden of deaths and DALYs.

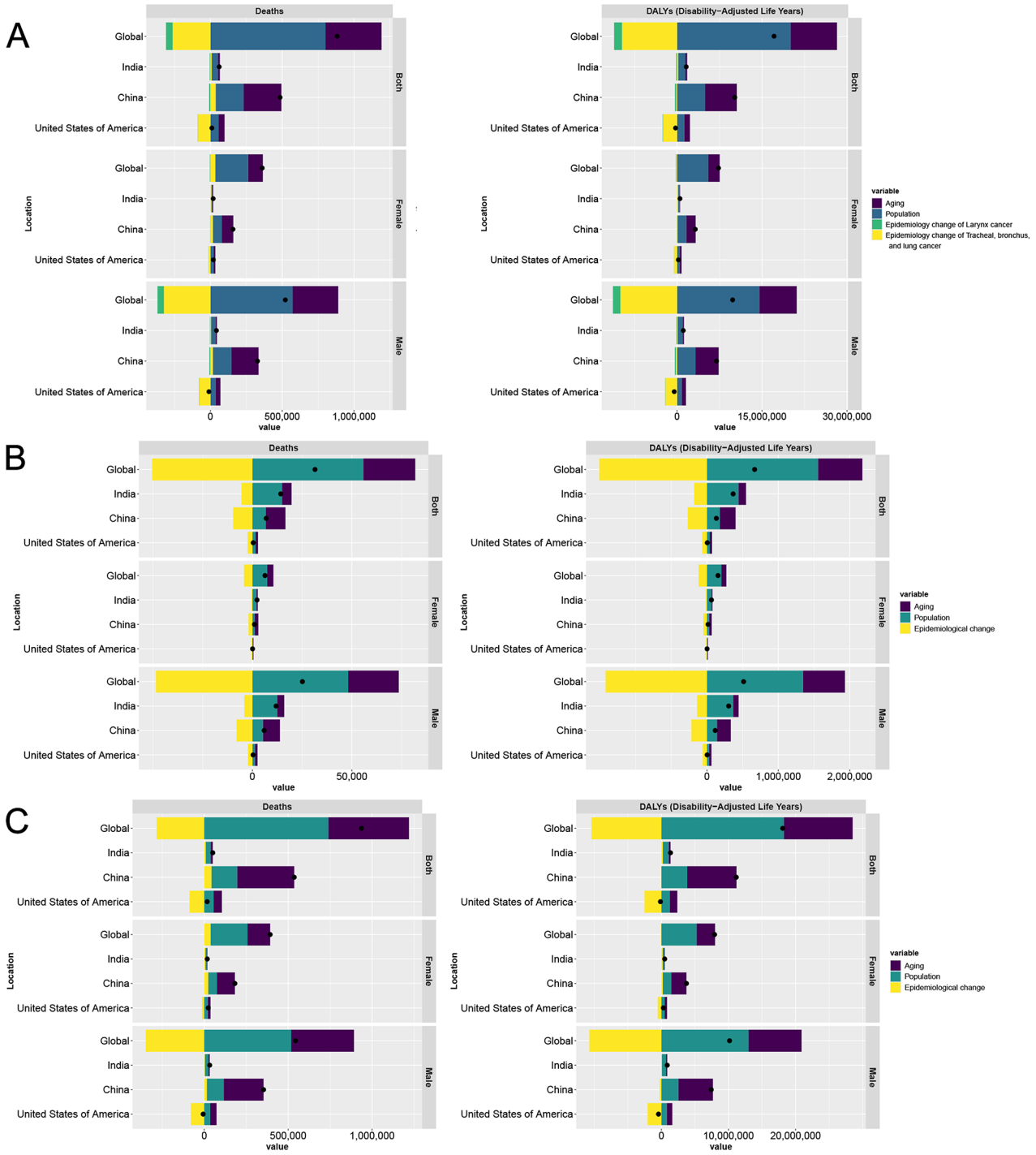

Fig. 7 Decomposition analysis results of respiratory tract cancers-related deaths and DALYs. (**A**) Different decomposition factors for respiratory tract cancers Globally, in India, China, and the United States, by gender (**B**) Different decomposition factors for larynx cancer (**C**) Different decomposition factors for TBL cancer

When examining the impact of disease, population growth emerged as the predominant factor contributing to the rising burden of deaths and DALYs associated with larynx and TBL cancers on a global scale, as well as specifically in the United States and India. In China, however, ageing was identified as the primary driver behind the increasing mortality burden from larynx cancer, while epidemiology developments noticeably was contributed to the escalating DALYs burden related to this condition (Fig. 7C-D). Furthermore, ageing remained

a critical determinant influencing the TBL cancer burden within China.

Health inequality analysis

To elucidate socioeconomic differences in the burden of respiratory tract cancers, we used SII and CIX methods to examine crude Deaths and DALYs rates at different socio-demographic index (SDI) levels from 1990 to 2021, and performed health inequality analyses for larynx and TBL cancers, respectively.

The results of the SII showed that in 1990, the difference in crude deaths rates caused by larynx cancers between areas with the highest (SDI = 1) and lowest SDI regions was 1.44 (lower in areas with SDI of 1), the difference was slightly decreased to 1.28 by 2021 (Fig. 8A). In 1990 and 2021, the crude deaths rate in the United States was lower than in regions with the same SDI, while it was higher in India and equal in China. At the same time, CIX for larynx cancer deaths decreased from 0.16 (95%CI: 0.11 to 0.21) in 1990 to 0.08 (95%CI: 0.04 to 0.12) in 2021. Regarding DALYs for larynx cancer, SII decreased from about 37 per 100,000 DALYs in 1990 to about 29 per 100,000 DALYs in 2021 (Fig. 8B). Similar to mortality, DALY rates were lower than expected in the United States, higher in India, and in line with expectations in China. The CIX of larynx cancer DALYs also changed markedly, decreasing from 0.14 (95%CI: 0.09 to 0.20) in 1990 to 0.05 (95%CI: 0.00 to 0.09) in 2021. The results showed that with the progress of time, the burden of high SDI level was gradually reduced. However, the disease burden in India was increasing due to rapid population growth. From 1990 to 2021, the disparities in crude deaths of TBL cancer decreased. The gap between the regions with the highest (SDI = 1) and lowest (SDI = 0) SDI had increased from about 35 deaths per 100,000 people in 1990 to 45 deaths per 100,000 people in 2021 (Fig. 8C). When countries' death rates were compared to regions with the same SDI, the US and China were consistently lower than expected, while India was higher. The corresponding CIX for death did not change markedly, increasing from 0.43 (95%CI:0.39, 0.48) in 1990 to 0.45 (95%CI: 0.41, 0.49) in 2021. The distribution of TBL cancer's deaths burden was more uneven in different socioeconomic backgrounds, and the deaths burden was lower in the group with high SDI. The gap between the highest and lowest SDI regions increased from 878 DALYs per 100,000 people in 1990 to 954 DALYs per 100,000 people in 2021 (Fig. 8D). The results of DALYs compared with expectations were consistent across countries in terms of deaths. The US and China consistently beat expectations, while India fell short. The CIX for TBL cancer DALYs remained constant from 0.41 (95% CI: 0.36, 0.45) in 1990 to 0.41 (95% CI: 0.37, 0.45) in 2021, indicating a higher burden persistence in areas with high SDI.

Future projections of respiratory tract cancers burden

Based on the respiratory tract cancers burden from 1980 to 2021, we used BAPC model to predict changes of respiratory tract cancers burden in the global, China, the United States, and India from 2022 to 2050 (Fig. 9). The results showed that the respiratory tract cancers in death and DALYs were increase trend, and there was a noticeable gender difference. The number of laryngeal cancer deaths globally in 2050 reached 179 thousand cases, of which 149 thousand cases were in males and 30 thousand cases in females, an increase of 53% compared to 2021. Among them, the number of deaths in India was projected to reach 59 thousand cases (an increase of 107.5% from 2021), with a predominance of males (51 thousand cases, 109.3%). China projected a 62.2% increase in the number of deaths from 2021 (to 32 thousand cases). The United States has the smallest increase in 2050 deaths of the three countries (15%, only 5 thousand cases). The results showed that ASR-Deaths and ASR-DALYs of

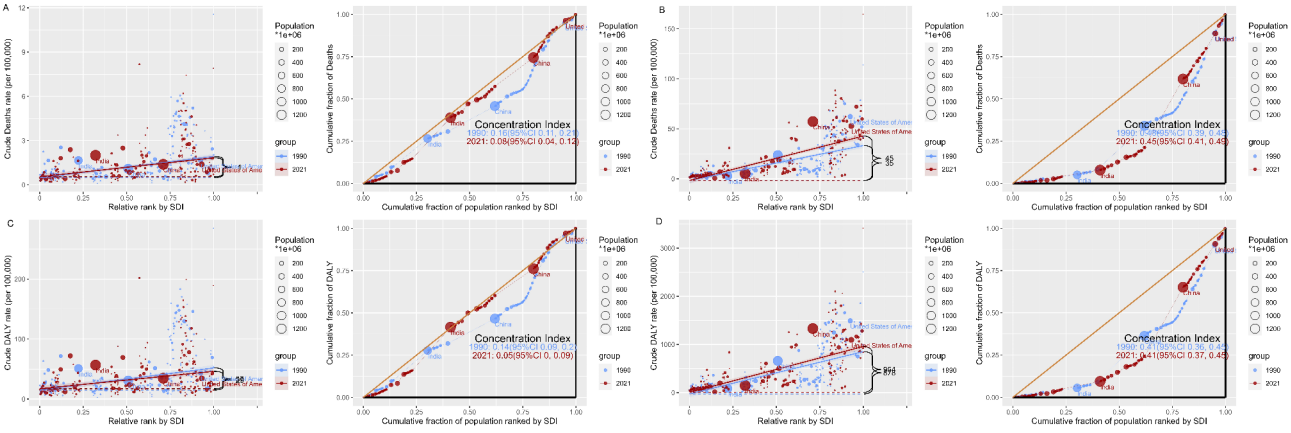

Fig. 8 Visualization of SII and CIX Results of Deaths and DALYs. (**A**) The SII and CIX analysis of Deaths for larynx cancer (**B**) The SII and CIX analysis of DALYs for larynx cancer (**C**) The SII and CIX analysis of Deaths for TBL cancer (**D**) The SII and CIX analysis of DALYs for TBL cancer

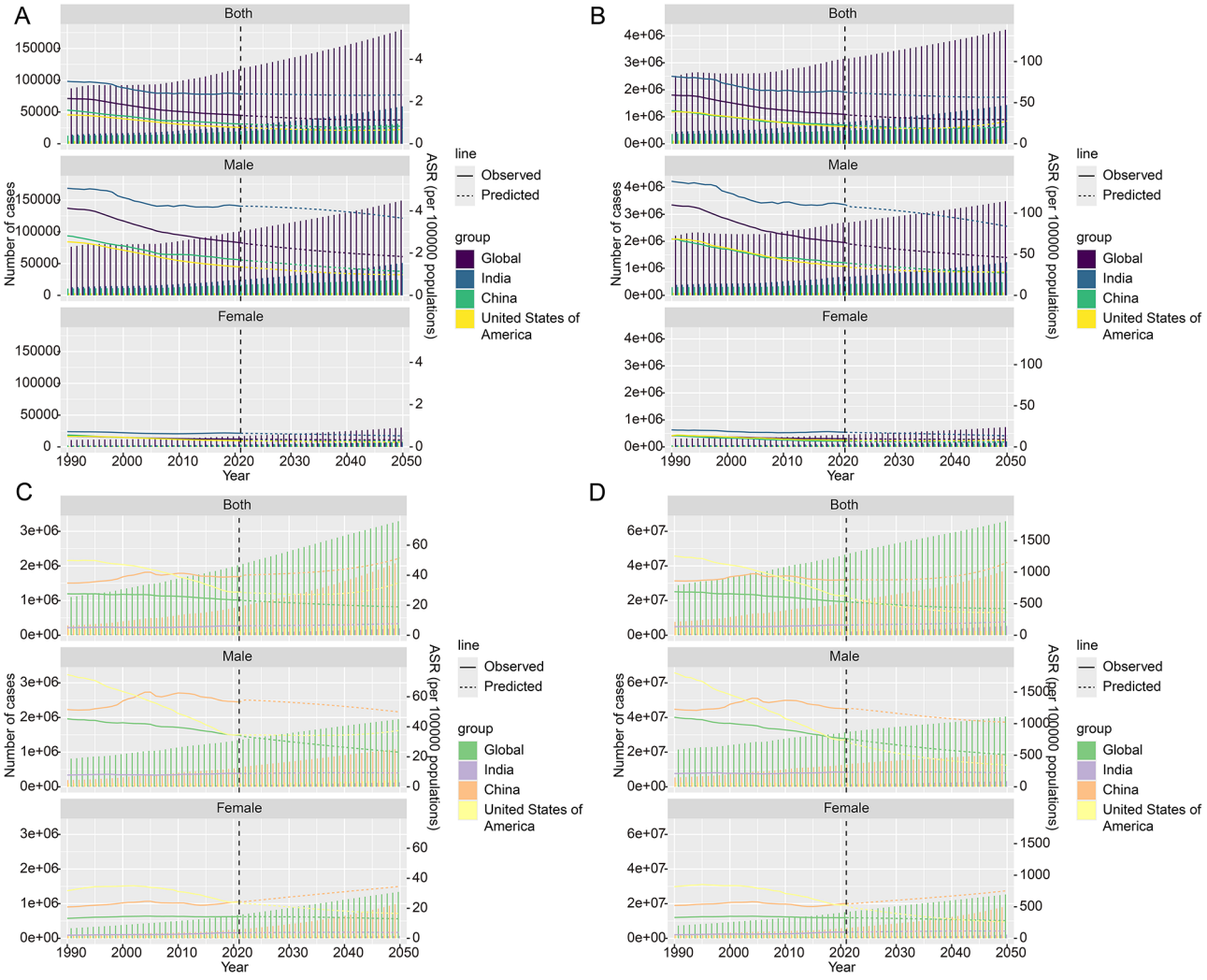

Fig. 9 Predictions of Respiratory Tract Cancers burden using the BAPC forecasting model (up to 2050). (**A**) BAPC model predicted larynx cancer ASR-Deaths (**B**) BAPC model predicted larynx cancer ASR-DALYs (**C**) BAPC model predicted TBL cancer ASR-Deaths (**D**) BAPC model predicted TBL cancer

larynx cancer were predicted to continue to decline. By 2050, the number of TBL cancer deaths worldwide would reach 3 million cases (2 million in men and 1 million in women, and an increase of 63.2% from 2021). Of these, 2 million cases were in China, 297 thousand cases in the United States and 198 thousand cases in India. The ASR-Deaths projections of TBL cancer were different, with a steady decline in global, and a steady increase in China and the United States. In China, the death-ASR gradually declined for males and increased for females, while in the United States the trend was reversed for both genders. India was expected to increase, but not much. On the other hand, DALYs of TBL cancer were projected to decline steadily in the future in global and the US, with slight increases in China and India. It was noteworthy that males in China showed a trend of decreasing for ASR-Deaths and ASR-DALYs in the future, while females showed the opposite trend. In all regions analyzed, males consistently exhibited higher ASR-Deaths and ASR-DALYs relative to females.

Age-specific projections of respiratory tract cancers burden

In addition, we employed the BAPC model to predict age-specific cohorts affected by larynx and TBL cancers (Fig. 10). Specifically, we focused on larynx cancer patients aged 50–74 years and TBL cancer patients aged 55–79 years. Overall, for larynx cancer, males bore more serious health burden than females, and the burden of females tended to be stable. Specifically, larynx cancer patients aged 50–74 years differed by region in 2021–2050. ASR-Deaths and ASR-DALYs showed a downward trend globally and in China, and fluctuated down in the United States. In India, future trends vary by age group. The rate of TBL cancer deaths fluctuated but stabilized in the 65–74 age group, with a small decline in the under-64

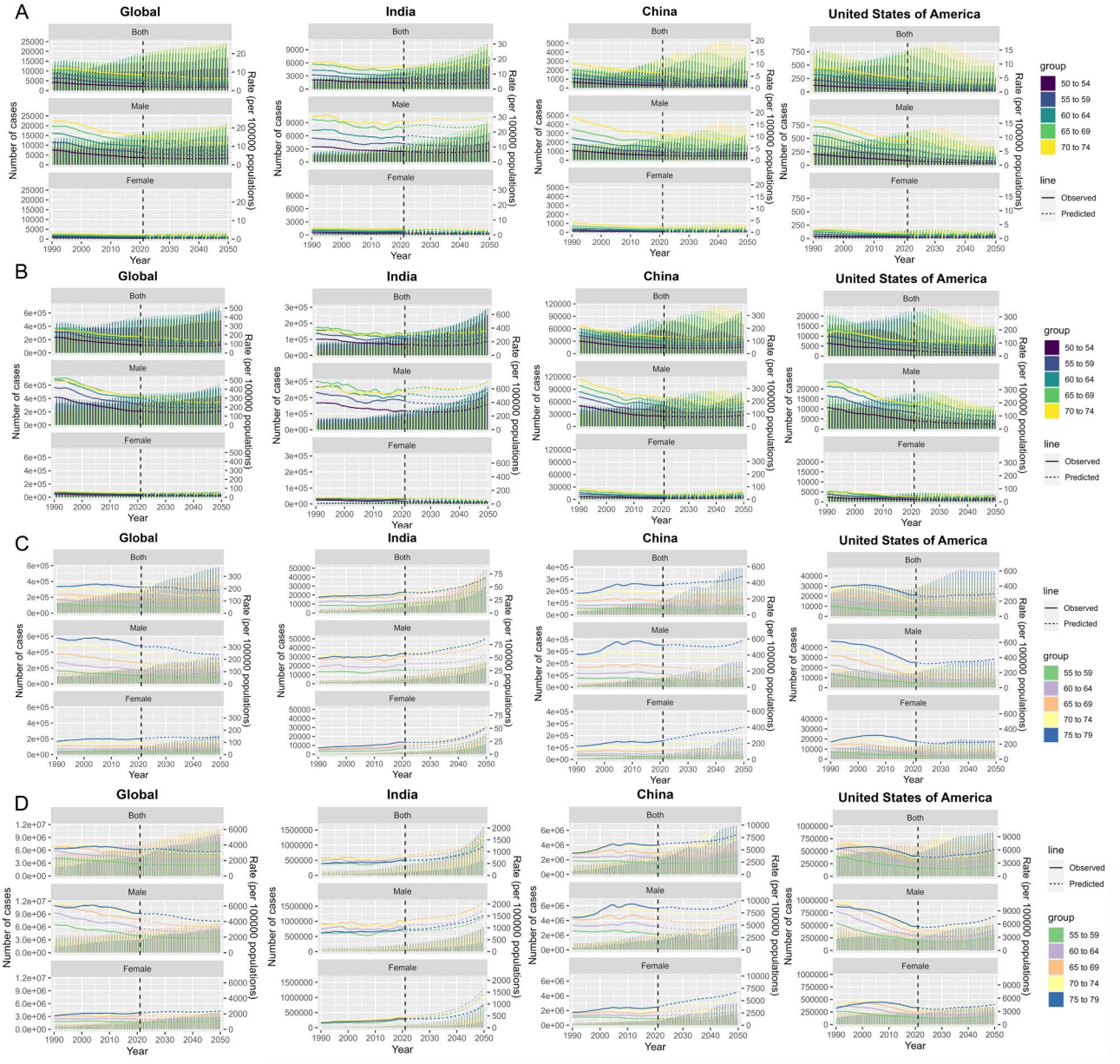

Fig. 10 Prediction of Deaths-ASR and DALYs-ASR for specific age-cohorts affected by Respiratory Tract Cancers. (**A**) BAPC model predicted larynx cancer Deaths-ASR in the 50-74 years age group (**B**) BAPC model predicted larynx cancer DALYs-ASR in the 50-74 years age group (**C**) BAPC model predicted TBL cancer Deaths-ASR in the 55-79 years age group (**D**) BAPC model predicted TBL cancer DALYs-ASR in the 55-79 years age group

age group. As for DALYs-ASR, 50–74 age group tend to be stable.

The forecast analysis showed that the global ASR-Deaths and ASR-DALYs rates for TBL cancer in people aged 55–79 years will continue to decline steadily after 2021. Unlike the trend of small fluctuations before 2021, India showed a rapid upward trend after 2021, which needs attention. In China, TBL cancer ASR-Deaths and ASR-DALYs rates in the 55–79 age group had either stabilized or increased slightly. Specifically, the burden of males will change little, while the burden of females predicted to increase markedly, indicating the future transformation of the male-female ratio of TBL cancer in China. TBL cancer ASR-Deaths and ASR-DALYs in the United States just experienced a period of decline until 2021, but slowly increased or stabilized after 2021.

Discussion

Based on the latest GBD data, this study conducted a comprehensive analysis of the evolving trends in the burden of respiratory tract cancers. The findings indicated that both the disease burden and future projections vary noticeably across different countries. In 2021, laryngeal cancer was responsible for an estimated 117 thousand

deaths globally, including 20 thousand in China, 28 thousand in India, and 5 thousand in the United States. Collectively, these three populous nations accounted for nearly half of the global burden. Deaths of TBL cancer, meanwhile, was 2017 thousand people globally in 2021, 814 thousand in China, 175 thousand in the United States, and 75 thousand in India. The combined burden of three countries was already more than half of the global burden. The impact of respiratory tract cancers in these populous countries requires extensive attention from global health authorities.

From 1990 to 2021, deaths and DALYs of larynx cancer decreased globally (AAPC for deaths was − 1.47 and AAPC for DALYs was − 1.61). This trend may be linked to tobacco control policy of WHO [6] and the improvement of treatment methods in recent years [7]. While there was a slight downward trend in the burden of TBL cancer (AAPC for deaths was − 0.54 and AAPC for DALYs was − 0.86), the persistently high burden required attention. The slower rate of decline for TBL cancer may be due to the long latency period between risk factor exposure and cancer development, as well as an increase in other risk factors such as air pollution [8]. Country-specific, deaths and DALYs from larynx cancer also decreased significantly in China, whereas TBL cancer showed an increasing trend (AAPC for death was 0.38 and AAPC for DALYs was 0.06). Among them, there was a rapid increase from 1997 to 2004 (APC for deaths was 2.23 and APC for DALYs was 1.59). This phenomenon may be associated with the high smoking rates in China and the lack of public health awareness [9]. From 2014 to 2021, the burden of deaths and DALYs due to TBL cancer in China remained significant, although it exhibited fluctuations leading to a gradual decrease. Smoking remained a major contributor to the rise in deaths and DALYs in China. The tobacco epidemic was better controlled than in many developed countries, but in China and other developing countries, tobacco prevalence continues to rise [10]. This situation necessitates the comprehensive implementation of tobacco control policies, early screening for cancer, and ongoing advancements in treatment methodologies to mitigate future mortality burdens [11–13]. The decreasing trend of larynx and TBL cancer burden in the United States was more obvious than the global average (AAPC < -1.5). This observation suggests that the public health policies and medical systems in the United States are relatively well-developed, providing valuable experience in preventing and treating respiratory tract tumors. Contributing factors include rapid development and approval of targeted therapies and immunotherapies within the U.S., effective smoking control measures, as well as successful efforts aimed at mitigating environmental pollution [14–16]. On the other hand, India saw an increase in TBL cancer burden (AAPC 0.69 for deaths and 0.57 for DALYs) and a slight decrease in laryngeal cancer burden, showing a complex pattern of change. This could be attributed to factors such as increased urbanization and changes in lifestyle [17].

The study further conducted a stratified analysis of DALYs and deaths related to larynx cancer and TBL cancer in 2021 globally, China, the United States, and India by sex and age. The results showed that the burden of larynx cancer and TBL cancer was noticeably different between males and females, with males experiencing a notably higher burden than females. Previous studies reached the same conclusion [18, 19]. This is related to with factors such as higher tobacco and alcohol consumption among males, hormonal characteristics, genetic predispositions, etc [20–22]. The need for gender-specific interventions was highlighted. In addition, respiratory tract tumors demonstrated a pronounced tendency towards aging. Consistent with prior studies [23], deaths and DALYs rates predominantly peaked within the 60–74 age group across various countries. This finding emphasized the importance of developing targeted screening and prevention strategies tailored to these age demographics.

The APC analysis provided us with the opportunity to understand changes in respiratory tract cancer burden from different dimensions. For larynx cancer, the global and Chinese DALYs-ASR arched with age, which may reflected age-related biological mechanisms, such as declining immune function with age. However, India and the United States did not see a significant decline in the older age group, which may be attributed to advances in larynx cancer treatment that extended patient survival. This observation emphasized the necessity for developing different prevention and treatment strategies for different age groups. In terms of period, the peak in global, as well as in India and the United States occurred in 1992–1996, while the peaks in China occurred in 2002–2006. This difference in timing may reflected differences in the implementation of tobacco control policies and progress in cancer treatment in different countries. The peak occurred later in China, which may be related to its economic development trajectory and subsequent lifestyle transformations. Cohort-effect analysis showed that, with the exception of India, deaths for TBL cancer in other countries showed a slight increase followed by a rapid decline as the cohort progressed. This may reflected changes in lifestyle between generations, particularly changes in smoking habits. Notably, deaths of TBL cancer increased over time in the same cohort, began with the cohort born between 1922 and 1937, which may be related to the long-term environmental and occupational exposures experienced by these cohorts. The APC analysis also revealed some interesting interactions. For example, DALYs-ASR presented a left-skewed arched

distribution over the same period, eventually settled to a low level. This may reflected the cumulative effect of prevention and treatment measures, but the effect changed across age groups and cohorts. These findings provided an important basis for formulating targeted public health policies. The unique APC model of China reflected that more attention needed to be pay for cancer prevention and treatment in the elderly population, while strengthening health education for younger cohorts. For India, given its continued upward trend, more aggressive tobacco control measures and environmental protection policies may be needed. However, we noticed some limitations of the APC analysis. For example, there was an inherent multicollinearity between age, period, and cohort effects, which could lead to problems with model recognition. In addition, the APC analysis was primarily descriptive and cannot directly infer causality. Therefore, these findings should be combined with results from other types of studies to form a more complete understanding. Overall, the APC analysis provided us with a multi-dimensional framework for understanding changes in burden of respiratory tract cancer, revealing the complex interplay of age, period, and cohort effects. These insights not only helped us understand past trends, but also provided an important basis for predicting future changes and developing targeted interventions.

The main factors influencing the burden of respiratory tract tumors were studied by a decomposition analysis. Globally and in India, population growth was the main driver of the increased burden of respiratory tract cancers in deaths and DALYs, with ageing being the second most important factor. At the same time, changes in the epidemiology of TBL cancer also played an important role in reducing the burden of disease. In the United States, epidemiology played the most important role in the changing burden of respiratory tract cancers. On the one hand, it significantly promoted the reduction in deaths (-491.13%), and on the other hand, it promoted the increase in DALYs (1815.4%). These demonstrated the need for disease control, management and intervention in the health care system. However, in China, ageing was the most important reason affecting the burden of respiratory tract cancers, and the effect of epidemiological changes was not obvious. China already faced problem with ageing and predicted to get worse in the future [24], so appropriate policies were needed to avoid an even greater burden of disease. Population growth was the second largest cause of increased respiratory cancer burden in China, which may lead to increased social and medical economic burden, consistent with the findings of a previous study [25]. Different countries have different characteristics, and individualized interventions are needed to reduce the disease burden of respiratory tumors.

Analyses of health inequalities at different economic levels showed differences across countries. The CIX for larynx cancer decreased from 0.16 in 1990 to 0.08 in 2021, indicating an improvement in health inequalities. However, the CIX for TBL cancer increased from 0.43 in 1990 to 0.45 in 2021. Although the difference was not obvious, it also indicated that the distribution differences in different socioeconomic backgrounds were still expanding. It is noteworthy that the burden of larynx and TBL cancers in both India and the United States increased in 2021, while the United States decreased. At the same time, a positive CIX value indicated better health in areas with high SDI, consistent with previous studies [26, 27]. This reflected the inequality of medical resources and development. These findings suggest that health inequalities in patients with respiratory tumors need to be addressed, especially in areas with low SDI levels.

Projections based on the BAPC showed that the global burden of larynx cancer was likely to continue to decline, which is a positive sign. However, the burden of TBL cancer was expected to increase in China, especially among females. This was consistent with the trend observed in existing studies [28] and needed to pay more attention. The American Cancer Society also paid attention to the issue of female TBL cancer, which was the result of a complex combination of factors [29]. TBL cancer without a history of smoking was more common in females than in males [30]. Air pollution, occupational exposure, and non-second-hand smoke exposure were also important risk factors for TBL cancer [31–33]. China had a heavy burden of air pollution for decades [34], and measures were improving and effective [35, 36], so there may be some lag in the improvement of TBL cancer in deaths and DALYs. At the same time, TBL cancer screening for females also needs to be further developed. In addition, traditional Chinese medicine has demonstrated efficacy in the treatment of TBL cancer [37]. In the future, China can leverage its strengths in this field to enhance therapeutic outcomes. On the other hand, the TBL cancer burden in India was projected to continue to rise, which is partly linked to the tobacco epidemic in India [38]. Comprehensive tobacco control strategies, such as tobacco taxes, schooling, media campaigns, and legal bans, were needed to address major tobacco control challenges [39, 40]. The necessary air pollution control is equally important for India [41].

This study has some limitations. First, the quality of GBD data can vary across countries and regions, which can affect the accuracy of the results. Second, this study fails to investigate the specific causes of the observed trends, which require further investigation. Finally, the BAPC model's predictions are based on historical data

and may not fully capture the sudden changes that may occur in the future.

Conclusion

Overall, this study provided a comprehensive analysis of the global respiratory tract cancer burden from 1990 to 2021, revealing trends and characteristics in different regions. The study found that deaths and DALYs from laryngeal and TBL cancers are generally declining globally, but with significant variations across countries. Among the three populous countries, the burden of both laryngeal and TBL cancers declined significantly in the United States (AAPC < -1.5); the burden of laryngeal cancer declined in China, but TBL cancers were on the rise (AAPC for deaths of 0.38 and AAPC for DALYs of 0.06). And the burden of TBL cancers continued to increase in India (AAPC for deaths of 0.69 and AAPC for DALYs of 0.57). Gender-stratified analysis showed that the disease burden was significantly higher in males than in females and was concentrated in the 60–74 age group. The future projections indicate that the burden of TBL cancer in Chinese women may continue to rise, a trend that is cause for concern.

These findings carry important implications for public health policymaking, suggesting the need to (1) strengthen preventive measures such as tobacco control, especially in developing countries such as China and India; (2) the US model (e.g., smoking bans, early detection) should be used as a reference for global strategies. (3) Differentiated screening and prevention strategies should be developed for different genders and age groups; (4) Global efforts should be made to address population ageing and socio-economic disparities, and to improve equity in the distribution of healthcare resources, with a focus on regions with lower levels of socio-economic development; (5) Environmental protection measures should be strengthened to reduce air pollution. Implementation of these interventions will help to further reduce the global burden of respiratory tract cancer.

Abbreviations

DALYs	Disability-adjusted life years
TBL	Tracheal, bronchus, and lung
SDI	Socio-demographic index
AAPC	Average annual percent change
BAPC	Bayesian Age-Period-Cohort
GBD	Global Burden of Disease
ASR	Age-standardized rate
WHO	World Health Organization
SII	Slope index of inequality
CIX	Concentration index

Supplementary Information

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Supplementary Material 1

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Author contributions

Xinxin Liu, Guoyu Wang and Yafei Chen wrote the main manuscript text. Bozhen Huang, Shanshan Song and Siyi Ma made pictures visual. Wanqing Wang and Luyao Wang were responsible for supervision. Min Jiang, Yafei Chen, and Guoyu Wang presented the concept. All authors reviewed the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The study did not need approval because it used publicly available data.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Traditional Chinese Medicine, Beijing Shijitan Hospital, Capital Medical University, Beijing 100038, China
[2]Institute of Basic Research in Clinical Medicine, China Academy of Chinese Medical Sciences, Beijing 100700, China
[3]Department of Respiratory and Critical Care Medicine, Affiliated Hospital of Shandong University of Chinese Medicine, Jinan 250011, China

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