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Long-term trends and future projections of larynx cancer burden in China: a comprehensive analysis from 1990 to 2030 using GBD data

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Larynx cancer poses a significant public health challenge in China, with rising incidence and mortality rates over the past decades. Understanding the long-term trends and underlying factors is crucial for effective intervention and policy formulation. Data were utilized from the global burden of disease (GBD) Study 2021 to analyze the incidence, prevalence, mortality, disability-adjusted life years (DALYs), years lived with disability (YLDs), and years of life lost (YLLs) due to larynx cancer in China from 1990 to 2021. Joinpoint regression analysis identified key changes in trends, while age-period-cohort (APC) analysis and decomposition analysis quantified the contributions of aging, epidemiological changes, and population growth to these trends. Our study found a significant increase in the incidence and prevalence of larynx cancer in China, particularly among males. The age-standardized incidence rate (ASIR) and age-standardized mortality rate (ASMR) for males were substantially higher than those for females. Decomposition analysis revealed that aging was the primary driver of increasing incidence and mortality rates, while epidemiological changes had a mitigating effect. Joinpoint analysis identified periods of rapid urbanization and economic growth as key turning points for increased incidence. Bayesian APC models projected a continued upward trend in incidence rates up to 2030. The rising burden of larynx cancer in China underscores the need for targeted public health interventions, including smoking cessation programs, environmental pollution control, and early detection strategies. Addressing gender disparities and implementing effective prevention measures are crucial to mitigating the impact of larynx cancer in China.

Keywords Larynx cancer, China, Incidence, Prevalence, Mortality, Disease burden, Bayesian age-period-cohort analysis, Gender disparities, Aging, Epidemiological changes

Larynx cancer is one of the most prevalent malignancies within the head and neck region, significantly impacting global health. In 2022, larynx cancer accounted for approximately 103,216 deaths worldwide, with age-standardized incidence and mortality rates of 3.9 and 2.1 per 100,000, respectively[1]. The incidence and mortality rates of larynx cancer vary significantly by region, influenced by factors such as tobacco and alcohol use, occupational exposures, and socioeconomic status[2]. Tobacco use remains the primary risk factor, with alcohol consumption acting synergistically to increase the risk. Occupational exposure to asbestos, wood dust, and certain industrial chemicals also contributes to larynx cancer risk. Despite advancements in medical technology and early detection, the burden of larynx cancer remains high, particularly in low and middle-income countries where access to healthcare is limited[3]. The disparities in healthcare infrastructure and preventive measures lead to delayed diagnoses and suboptimal treatment outcomes in these regions.

Previous studies have underscored the significant disparities in larynx cancer burden across different regions and demographic groups. For example, the Global Burden of Disease Study (GBD) 2017 reported that East Asia experienced the highest increases in age-standardized incidence, disability-adjusted life years (DALYs), and death rates for larynx cancer from 2007 to 2017[4]. The study attributed these increases to rapid urbanization, industrialization, and lifestyle changes, including increased tobacco use. Furthermore, the highest

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age-standardized incidence, DALY, and death rates were observed in regions with low socio-demographic index (SDI) quintiles, underscoring the need for targeted interventions in these areas[5]. The disparities are also reflected in access to cancer screening and treatment facilities, with low SDI regions having fewer resources for early detection and effective management of larynx cancer. However, these studies often lack detailed projections of future trends and do not adequately account for the complex interplay of aging, epidemiological changes, and population factors.

In China, the burden of larynx cancer has been rising steadily over the past decades. A study analyzing data from 1990 to 2017 indicated that China had one of the highest percentage increases in age-standardized incidence, DALY, and death rates for larynx cancer globally[6]. This increase has been attributed to factors such as high smoking prevalence, environmental pollution, and occupational hazards. The high smoking rates among Chinese men, combined with increasing air pollution levels, have been significant contributors to the rising larynx cancer incidence. Despite these alarming trends, there remains a critical gap in the current literature regarding the long-term projections and detailed analysis of the factors driving these trends in China. Recent projections using Bayesian age-period-cohort (BAPC) models predict a continuous upward trend in larynx cancer incidence rates in China up to 2030, with significant gender differences in the burden of disease[7]. These findings highlight the urgent need for effective public health strategies to address the growing burden of larynx cancer in China, focusing on smoking cessation programs, reducing exposure to environmental pollutants, and improving early detection and treatment facilities. Implementing these strategies could mitigate the rising trends and improve overall survival rates for larynx cancer patients in China.

The purpose of this study is to provide a comprehensive analysis of the long-term trends in larynx cancer incidence, prevalence, and mortality in China and predict future trends up to 2030. Using the most recent data from the GBD Study 2021[8,9], this research will identify significant trends and their drivers, offering valuable insights for public health planning. Methodology includes analyzing data from the GBD Study 2021 using joinpoint regression and BAPC models to identify significant trends and predict future incidence rates. Decomposition analysis will be used to determine the contributions of aging, epidemiological changes, and population factors to changes in incidence and mortality.

Materials and methods

Data source

This study utilized data from the GBD Study 2021, which provides comprehensive and systematic assessments of disease burden across different regions and countries. The GBD database compiles data from a wide range of sources, including cohort studies, national health surveys, hospital records, and vital statistics registries, ensuring extensive coverage and reliability[8,10]. Data were extracted for the period from 1990 to 2021, focusing on larynx cancer in China, including incidence, prevalence, mortality, and DALYs, years lived with disability (YLDs), and years of life lost (YLLs).

Study design and population

The study included all-age populations in China, stratified by gender, to analyze trends in larynx cancer over three decades. Age-standardized rates were calculated to adjust for differences in age distribution over time and between populations. This method ensures that the observed trends reflect true changes in disease burden rather than demographic shifts.

Statistical analysis

Descriptive analysis

Descriptive statistics were used to summarize the annual number of cases, prevalence, incidence rates, mortality rates, DALYs, YLDs, and YLLs for larynx cancer. These metrics were reported separately for males and females to highlight gender disparities. Age-specific rates were also calculated to identify trends within different age groups.

Joinpoint regression analysis

Joinpoint regression analysis was employed to identify significant changes in trends over the study period. This method detects points where a statistically significant change in the linear slope of the trend occurs[11,12]. The Joinpoint Regression Program (version 5.2.0) was used to calculate the annual percentage change and identify key turning points in incidence, prevalence, and mortality trends. This analysis allowed us to pinpoint periods of significant increase or decrease in the burden of larynx cancer, providing insights into the effectiveness of public health interventions and changes in risk factor prevalence.

Age-period-cohort analysis

Age-period-cohort (APC) analysis was conducted to disentangle the effects of age, period, and cohort on the incidence and mortality rates of larynx cancer. The Bayesian APC (BAPC) model was used to project future trends up to 2030. This model allows for the simultaneous estimation of age, period, and cohort effects, providing insights into how these factors influence disease trends over time[13,14]. The APC analysis helps to understand the underlying demographic and temporal factors driving changes in larynx cancer incidence and mortality.

Decomposition analysis

Decomposition analysis was used to quantify the contributions of aging, epidemiological changes, and population growth to the observed changes in larynx cancer incidence and mortality. This method helps to identify the relative impact of these factors on disease trends, facilitating targeted public health interventions[15,16]. The decomposition analysis involved calculating the effect of each factor on the overall trend and determining whether it contributed to an increase or decrease in the burden of larynx cancer.

Data visualization
Data visualization was performed using R software (version 4.3.1) to create figures illustrating the trends in larynx cancer burden. Graphs included age-specific incidence, prevalence, and mortality rates, as well as the results of the joinpoint and decomposition analyses. Supplementary figures provided additional details on the gender-specific trends and projections. Visual representations were crucial for highlighting key findings and trends, making complex data more accessible and understandable.

Ethical considerations
This study used publicly available data from the GBD database, which does not require ethical approval. All methods were carried out in accordance with relevant guidelines and regulations.

Results
Incidence, prevalence, and mortality of larynx cancer in China, 2021
In 2021, the burden of larynx cancer in China exhibited significant gender disparities across incidence, prevalence, and mortality metrics. The total number of new larynx cancer cases was 38,905, with a marked male predominance of 32,510 cases compared to 6,394 cases among females. The age-standardized incidence rate (ASIR) was notably higher in males at 3.12 per 100,000 individuals, while females had a considerably lower rate of 0.58 per 100,000, leading to an overall incidence rate of 1.79 per 100,000 people (Table 1). Age-specific analysis showed that the incidence number peaked in the 65–69 age group for males, demonstrating a consistent male predominance (Fig. 1A). The incidence rate increased sharply from age 40, peaking in the 85–89 age group for males (Fig. 1B). The total prevalence of larynx cancer was 217,849 cases, with males accounting for 181,310 cases and females for 36,539 cases. The age-standardized prevalence rates (ASPR) were significantly higher in males at 16.86 per 100,000 compared to 3.27 per 100,000 in females, resulting in an overall prevalence rate of 9.86 per 100,000 individuals (Table 1). The highest number of prevalent cases was in the 65–69 age group for males (Fig. 1C), and prevalence rates were markedly higher in males across all age groups, with a sharp increase after age 40 (Fig. 1D). Mortality data further underscored these gender differences, with a total of 19,799 deaths due to larynx cancer, comprising 16,462 deaths in males and 3,338 in females. The age-standardized mortality rate (ASMR) was 1.68 per 100,000 for males and 0.3 per 100,000 for females, leading to an overall mortality rate of 0.94 per 100,000 individuals (Table 1). The number of deaths peaked in the 65–69 and 70–74 age groups for males (Fig. 1E), with death rates peaking in the 85–89 and 90–94 age groups, showing a substantial male predominance (Fig. 1F).

Burden of disease: DALYs, YLDs, and YLLs for larynx cancer in China, 2021
The impact of larynx cancer on population health, measured by DALYs, YLDs, and YLLs, revealed a considerable burden with pronounced gender disparities. The total DALYs due to larynx cancer were 493,848, with males accounting for 416,766 DALYs and females for 77,081. The age-standardized DALY rate was 39.58 per 100,000 for males and 7.01 per 100,000 for females, resulting in an overall rate of 22.73 per 100,000 individuals (Table 1). DALYs were highest in the 65–69 age group for males (Supplementary Fig. 1A), while age-specific DALY rates continued to increase with age and peaked in the 85–89 age group (Supplementary Fig. 1B). YLDs totaled 21,916, with males contributing 18,079 and females 3,837. The age-standardized YLD rate was 1.7 per 100,000 for males and 0.34 per 100,000 for females, with an overall rate of 1 per 100,000 individuals (Table 1). The highest number of YLDs was in the 65–69 age group for males (Supplementary Fig. 1C), but age-specific YLD rates showed a steady increase with age and peaked in the 85–89 age group (Supplementary Fig. 1D). YLLs, which capture the fatal impact of larynx cancer, totaled 471,932, with 398,688 YLLs among males and 73,244 among females. The age-standardized YLL rate was 37.88 per 100,000 for males and 6.66 per 100,000 for females, resulting in an overall rate of 21.73 per 100,000 individuals (Table 1). YLLs were higher in males across all age groups, peaking in the 65–69 age group (Supplementary Fig. 1E), with age-specific YLL rates increasing with age and peaking in the 85–89 age group (Supplementary Fig. 1F).

Measure	All-ages cases			Age-standardized rates per 100 000 people		
	Total	Male	Female	Total	Male	Female
Incidence	38905 (30370,49486)	32510 (24069,42391)	6394 (3873,8782)	1.79 (1.4,2.26)	3.12 (2.34,4.04)	0.58 (0.35,0.79)
Prevalence	217849 (171469,273851)	181310 (133834,234748)	36539 (23494,49819)	9.86 (7.81,12.35)	16.86 (12.58,21.67)	3.27 (2.11,4.44)
Deaths	19799 (15580,25023)	16462 (12222,21222)	3338 (1977,4603)	0.94 (0.74,1.17)	1.68 (1.27,2.13)	0.3 (0.18,0.42)
DALYs	493848 (382572,626010)	416766 (304821,544631)	77081 (46252,106174)	22.73 (17.67,28.65)	39.58 (29.17,51.44)	7.01 (4.19,9.66)
YLDs	21916 (14707,31457)	18079 (11557,26457)	3837 (2127,5846)	1 (0.67,1.43)	1.7 (1.1,2.49)	0.34 (0.19,0.52)
YLLs	471932 (365371,600068)	398688 (291237,520463)	73244 (43934,101356)	21.73 (16.9,27.46)	37.88 (27.96,49.07)	6.66 (3.99,9.22)

Table 1. All-age cases and age-standardized incidence, prevalence, deaths, DALYs, YLDs, and YLLs rates in 2021 for larynx cancer in China. *DALYs* disability-adjusted life-years, *YLDs* years lived with disability, *YLLs* years of life lost.

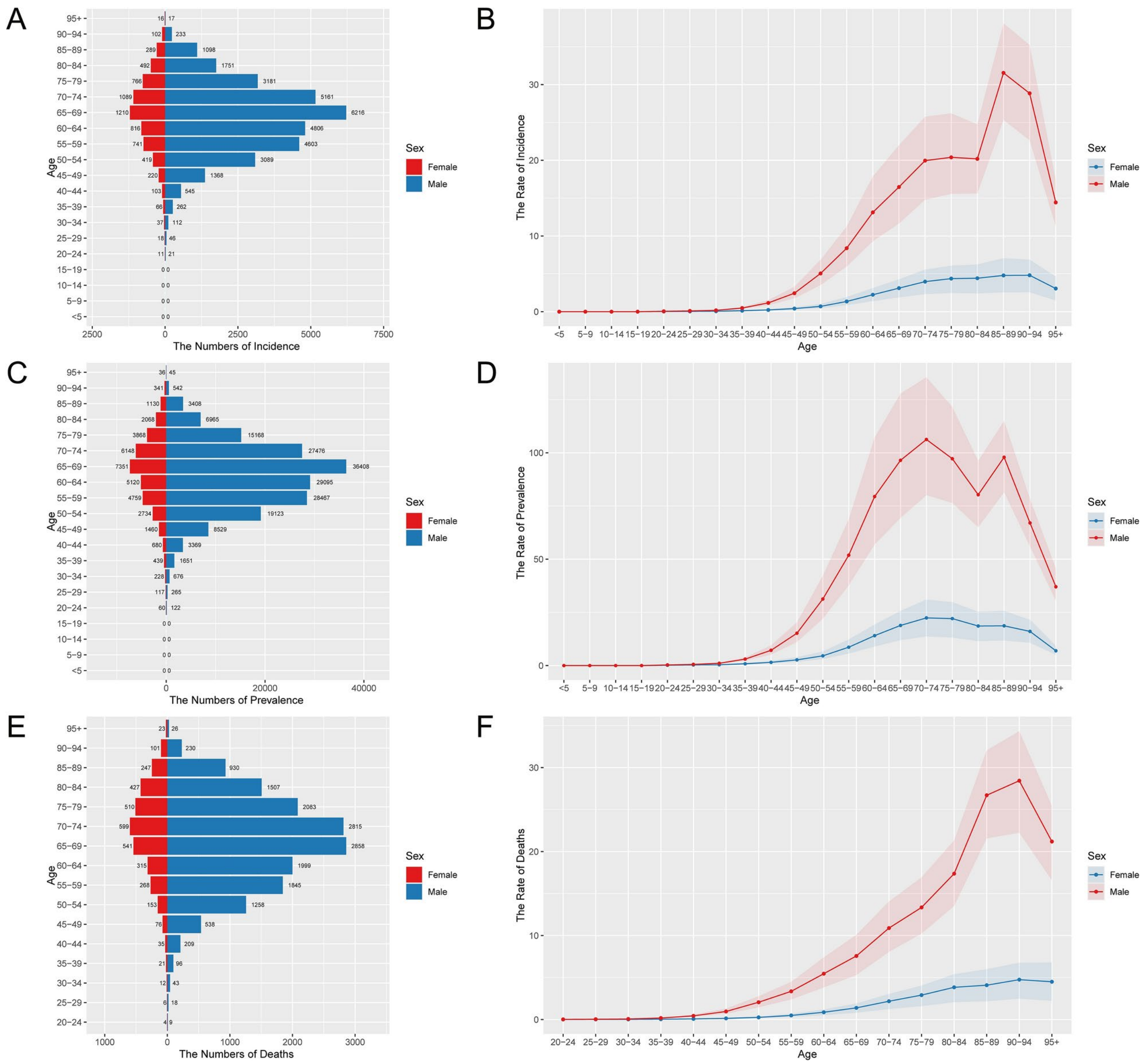

Fig. 1. Age-specific numbers and rates of incidence, prevalence, and deaths for larynx cancer in China, 2021. (**A**) The number of new larynx cancer cases (incidence) by age and sex. (**B**) ASIR of larynx cancer by sex. (**C**) The number of prevalent cases of larynx cancer by age and sex. (**D**) ASPR of larynx cancer by sex. (**E**) The number of deaths due to larynx cancer by age and sex. (**F**) ASMR from larynx cancer by sex. *ASIR* age-standardized incidence rate, *ASPR* age-standardized prevalence rate, *ASMR* age-standardized mortality rate.

Trends in incidence, prevalence, mortality, and disease burden of larynx cancer in China (1990–2021)

The analysis of larynx cancer trends in China from 1990 to 2021 reveals significant changes in incidence, prevalence, mortality, and disease burden, with distinct gender differences. Regarding incidence, the total number of cases has increased over the years. ASIR for males experienced a sharp increase between 2007 and 2012, followed by a slower rate of growth after 2012 (Fig. 2A). For females, ASIR initially declined during the early 1990s, followed by more stable trends and modest increases in recent years, particularly after 2015. The prevalence of larynx cancer also increased, with males showing consistently higher ASPR than females. Males exhibited a substantial rise in ASPR during the early 2000s, continuing to grow, albeit at a slower pace in later years. Females experienced a more gradual rise, with steady increases after 2015 (Fig. 2B). The mortality trends highlight notable gender differences. The ASMR for males declined significantly between 1990 and 2007 (Fig. 2C), followed by a rise from 2007 to 2011. However, the ASMR for males began to decline again from 2011 to 2021. In contrast, females showed a consistent decline in ASMR throughout the study period, with the most significant reductions occurring between 1992–1998 and 2001–2015, reflecting improvements in survival outcomes for females. In terms of disease burden, measured by DALYs, the total DALYs increased over time,

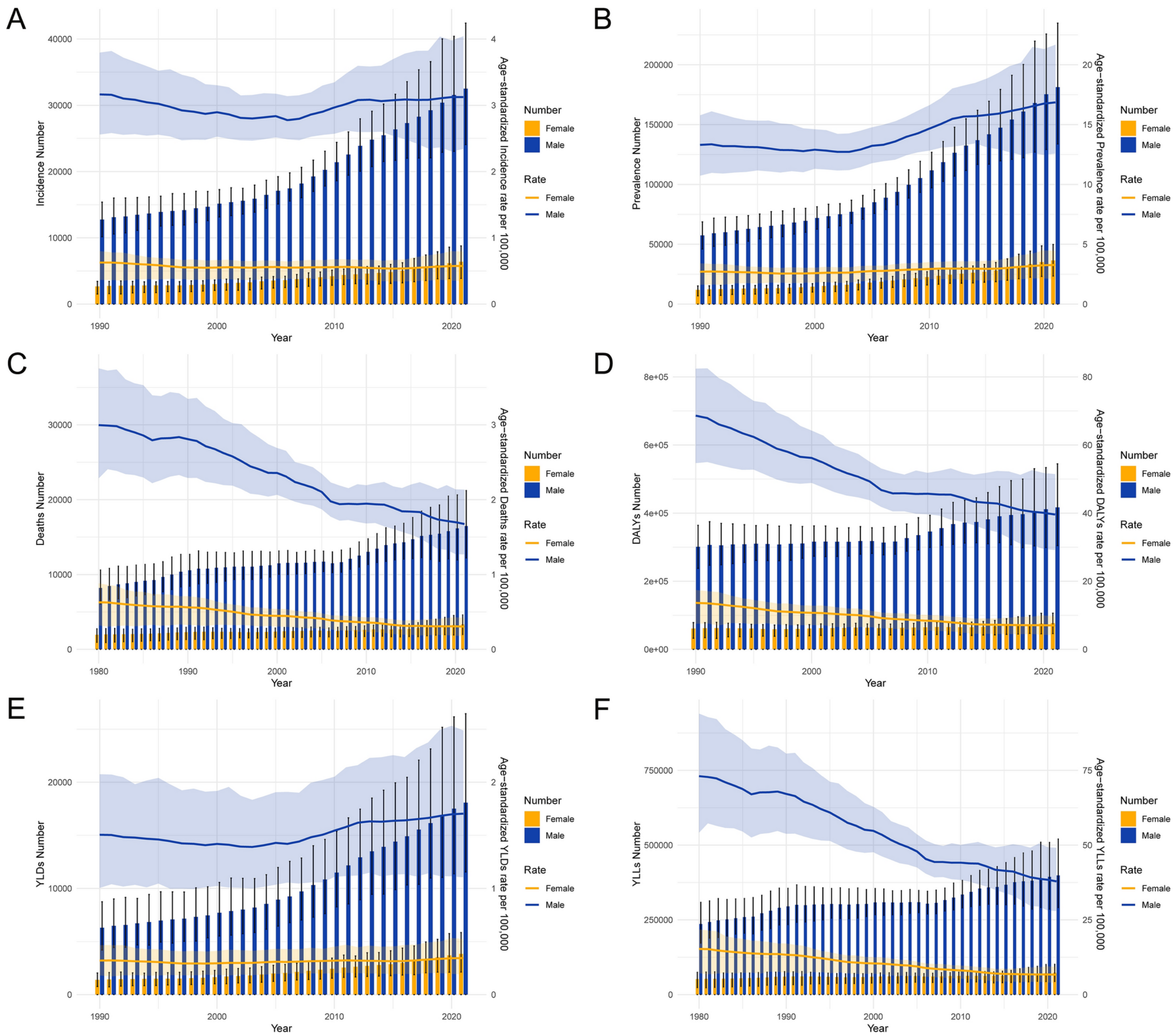

Fig. 2. Trends in numbers and age-standardized rates of incidence, prevalence, deaths, DALYs, YLDs, and YLLs for larynx cancer in China from 1990 to 2021, by sex. (**A**) The number of new larynx cancer cases (incidence) and ASIR per 100,000 people by year and sex. (**B**) The number of prevalent cases and ASPR per 100,000 people by year and sex. (**C**) The number of deaths and ASMR per 100,000 people by year and sex. (**D**) The number of DALYs and age-standardized DALY rates per 100,000 people by year and sex. (**E**) The number of YLDs and age-standardized YLD rates per 100,000 people by year and sex. (**F**) The number of YLLs and age-standardized YLL rates per 100,000 people by year and sex. *ASIR* age-standardized incidence rate, *ASPR* age-standardized prevalence rate, *ASMR* age-standardized mortality rate, *DALYs* disability-adjusted life years, *YLDs* years lived with disability, *YLLs* years of life lost.

though the age-standardized DALY rates decreased for both males and females. Males saw a substantial decline in DALY rates in the early 2000s, with subsequent fluctuations, while females experienced a steady downward trend (Fig. 2D). The YLD rates, representing the non-fatal burden, increased slightly, particularly for females, indicating a growing burden of disability. The YLL rates, which capture the fatal burden, showed a decline in both sexes, with males showing improvements in recent years and females maintaining a steady downward trend (Figs. 2E,F).

Trends in age-standardized rates of larynx cancer in China and globally (1990–2021)

The data from Table 2 and Fig. 3 highlight significant differences in the trends of age-standardized rates for various indicators of larynx cancer between China and the global context from 1990 to 2021. The ASIR in China showed a slight decrease from 1.82 to 1.79 per 100,000, a marginal change compared to the global ASIR, which saw a more substantial reduction from 3.07 to 2.29 per 100,000. This indicates that while incidence rates have declined globally, the trend in China has remained relatively stable. Prevalence trends depict a divergent pattern, with China experiencing a significant increase in the ASPR from 7.83 to 9.86 per 100,000. In contrast,

Measure	China			Global		
	1990	2021	Change	1990	2021	Change
Incidence	1.82 (1.5,2.13)	1.79 (1.4,2.26)	−0.10 (−0.23–0.04)	3.07 (2.92,3.23)	2.29 (2.13,2.47)	−0.95 (−1.01–−0.89)*
Prevalence	7.83 (6.47,9.13)	9.86 (7.81,12.35)	0.74 (0.59–0.89)*	15.27 (14.54,16.06)	12.56 (11.76,13.49)	−0.65 (−0.70–−0.61)*
Deaths	1.59 (1.32,1.86)	0.94 (0.74,1.17)	−1.46 (−1.64–−1.28)*	2.15 (2.01,2.28)	1.35 (1.26,1.45)	−1.18 (−1.22–−1.14)*
DALYs	40.37 (33.13,47.6)	22.73 (17.67,28.65)	−1.89 (−2.06–−1.73)*	59.3 (55.47,63.1)	35.8 (33.29,38.54)	−1.60 (−1.66–−1.55)*
YLDs	0.89 (0.6,1.21)	1 (0.67,1.43)	0.37 (0.21–0.54)*	1.58 (1.16,2.05)	1.25 (0.92,1.64)	−0.76 (−0.80–−0.72)*
YLLs	39.48 (32.45,46.49)	21.73 (16.9,27.46)	−1.68 (−1.84–−1.52)*	57.72 (54,61.38)	34.55 (32.15,37.13)	−1.31 (−1.36–−1.27)*

Table 2. Change of age-standardized rates in incidence, prevalence, deaths, DALYs, YLDs, and YLLs for larynx cancer between 1990 and 2021 in China and Global level. *DALYs* disability-adjusted life-years, *YLDs* years lived with disability, *YLLs* years of life lost. *P < 0.05 (permutation test).

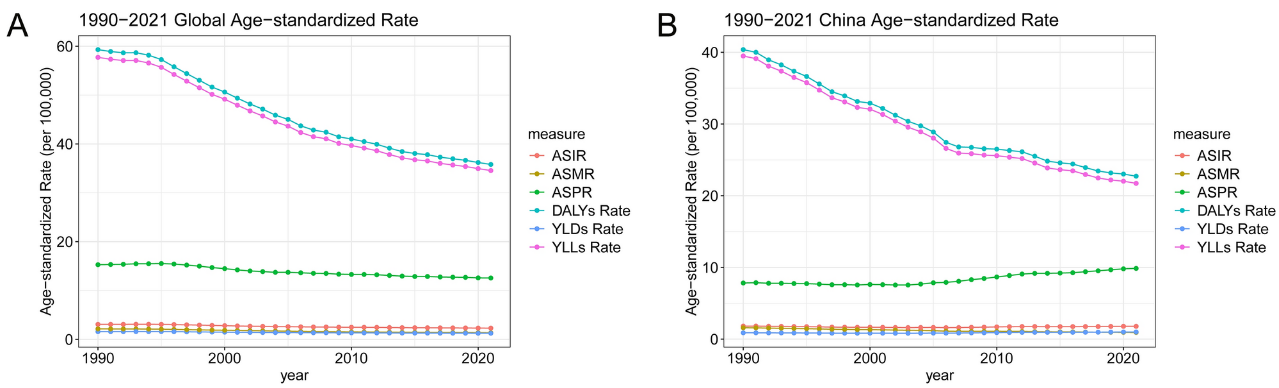

Fig. 3. Trends in global and China-specific age-standardized rates of incidence, prevalence, mortality, DALYs, YLDs, and YLLs for larynx cancer from 1990 to 2021. (**A**) Global age-standardized rates of larynx cancer incidence (ASIR), prevalence (ASPR), mortality (ASMR), DALYs, YLDs, and YLLs from 1990 to 2021. (**B**) China-specific age-standardized rates of larynx cancer incidence (ASIR), prevalence (ASPR), mortality (ASMR), DALYs, YLDs, and YLLs from 1990 to 2021. *ASIR* age-standardized incidence rate, *ASPR* age-standardized prevalence rate, *ASMR* age-standardized mortality rate, *DALYs* disability-adjusted life years, *YLDs* years lived with disability, *YLLs* years of life lost.

the global ASPR decreased from 15.27 to 12.56 per 100,000. This indicates an increasing burden of larynx cancer in China, contrary to the global trend of decreasing prevalence. Mortality trends, represented by the ASMR, show a notable decline in China from 1.59 to 0.94 per 100,000, a more significant reduction compared to the global decrease from 2.15 to 1.35 per 100,000. This suggests improved survival rates or effective management of larynx cancer in China.

The disease burden, measured by DALYs, YLDs, and YLLs, also reveals significant trends. In China, the age-standardized DALY rate decreased substantially from 40.37 to 22.73 per 100,000, while globally, it decreased from 59.3 to 35.8 per 100,000. This indicates an improvement in the overall health impact of larynx cancer in both contexts, with a more pronounced improvement in China. The YLD rates in China increased slightly from 0.89 to 1 per 100,000, contrasting with the global decrease from 1.58 to 1.25 per 100,000, suggesting an increase in the non-fatal burden of larynx cancer in China. Conversely, the YLL rates decreased significantly in China from 39.48 to 21.73 per 100,000, showing a better reduction compared to the global decrease from 57.72 to 34.55 per 100,000. These further underscores the improvement in managing and reducing premature mortality from larynx cancer in China.

Joinpoint regression analysis of larynx cancer burden in China, 1990–2021

The joinpoint regression analysis of age-standardized rates for larynx cancer in China from 1990 to 2021 revealed key trends and gender differences across various metrics. The ASIR initially decreased for both sexes in the 1990s, followed by periods of stability and slight increases in recent years. Males experienced a more prolonged decline, while females saw fluctuations, particularly with notable changes after 2015 (Table 3 and Fig. 4A). The ASPR increased for both males and females, with males experiencing distinct periods of growth in the mid-2000s. Females showed a gradual increase, particularly after 2015 (Table 3 and Fig. 4B). The ASMR generally decreased for both sexes, with significant reductions in the earlier years, followed by fluctuations in more recent years (Table 3 and Fig. 4C). In terms of burden, the age-standardized DALY rates reflected a downward trend for both sexes, with periods of decline in both males and females, while age-specific DALY rates showed notable variations across age groups (Supplementary Table 1 and Fig. 4D). The non-fatal burden, reflected in the age-standardized YLD rates, saw a slight increase in the later years, particularly for females, suggesting an ongoing

	ASIR			ASPR			ASMR		
Gender	Period	APC (95% CI)	AAPC (95% CI)	Period	APC (95% CI)	AAPC (95% CI)	Period	APC (95% CI)	AAPC (95% CI)
Both	1990–1999	−1.16 (−1.35–−0.96)*	−0.10 (−0.23–0.04)	1990–1998	−0.45 (−0.62–−0.28)*	0.74 (0.59–0.89)*	1980–1986	−1.07 (−1.53–−0.61)*	−1.46 (−1.64–−1.28)*
	1999–2007	−0.32 (−0.53–−0.11)*		1998–2003	−0.10 (−0.46–0.26)		1986–1990	0.14 (−1.01–1.31)	
	2007–2011	1.97 (1.15–2.79)*		2003–2007	1.66 (1.16–2.17)*		1990–2005	−1.95 (−2.04–−1.85)*	
	2011–2021	0.22 (0.02–0.43)*		2007–2012	2.40 (2.04–2.76)*		2004–2007	−3.61 (−4.96–−2.24)*	
				2012–2016	0.50 (−0.22–1.23)		2007–2011	−0.04 (−0.78–0.71)	
				2016–2021	1.32 (0.85–1.79)*		2011–2021	−1.55 (−1.73–−1.37)*	
Female	1990–1998	−1.83 (−2.07–−1.59)*	−0.31 (−0.48–−0.14)*	1990–1994	−0.43 (−1.04–0.17)	0.62 (0.40–0.83)*	1980–1992	−1.07 (−1.31–−0.83)*	−1.73 (−1.97–−1.49)*
	1998–2011	0.11 (−0.01–0.22)		1994–1997	−1.61 (−3.16–−0.02)*		1992–1998	−3.05 (−3.68–−2.41)*	
	2011–2015	−1.09 (−2.11–−0.06)*		1997–2002	0.62 (0.12–1.12)*		1998–2001	−0.48 (−3.18–2.29)	
	2015–2021	1.37 (0.92–1.82)*		2002–2011	1.42 (1.26–1.59)*		2001–2015	−2.54 (−2.69–−2.39)*	
				2011–2015	−0.37 (−1.16–0.44)		2015–2021	−0.41 (−1.06–0.25)	
				2015–2021	1.91 (1.56–2.26)*				
Male	1990–2002	−0.97 (−1.09–−0.85)*	−0.06 (−0.20–0.08)	1990–2003	−0.36 (−0.44–−0.29)*	0.75 (0.65–0.85)*	1980–1986	−1.18 (−1.62–−0.74)*	−1.44 (−1.61–−1.27)*
	2002–2007	−0.10 (−0.59–0.39)		2003–2007	1.72 (1.19–2.26)*		1986–1990	0.03 (−1.10–1.17)	
	2007–2012	1.87 (1.34–2.41)*		2007–2012	2.57 (2.20–2.94)*		1990–1994	−1.89 (−1.98–−1.80)*	
	2012–2021	0.13 (−0.13–0.38)		2012–2021	0.94 (0.77–1.12)*		2004–2007	−3.66 (−4.92–−2.38)*	
							2007–2011	0.22 (−0.48–0.91)	
							2011–2021	−1.52 (−1.70–−1.34)*	

Table 3. Joinpoint regression analysis: trends in age-standardized incidence, prevalence, mortality rates (per 100,000 persons) among both sexes, males, and females from 1990 to 2021 for larynx cancer in China. *AAPC* average annual percent change presented for full period, *APC* annual percent change, *CI* confidence interval. *P < 0.05 (permutation test).

rise in the non-fatal impact of larynx cancer (Supplementary Table 1 and Fig. 4E). The age-standardized YLL rates demonstrated a reduction in the fatal burden, particularly among males during the earlier years, with continued decreases in both sexes (Supplementary Table 1 and Fig. 4F). These patterns illustrate evolving trends in the incidence, prevalence, and outcomes of larynx cancer in China, with significant gender disparities in how the disease impacts different population groups.

Age, period, and cohort effects on incidence and mortality of larynx cancer in China

The analysis of age, period, and cohort effects on larynx cancer incidence and mortality in China reveals important trends across demographic groups. In Fig. 5A, prevalence rates increase with age, peaking in the 85–89 age group, with a rise after 2002, especially among older populations. Figure 5B similarly shows that incidence rates increase with age across all time periods. In Fig. 5C, the incidence rates for the 20–30 and 55 + age groups increased after 2002, while other age groups experienced a decline, indicating a shift in the burden of disease toward younger and older populations. Figure 5D shows a similar pattern, where recent birth cohorts exhibit increasing incidence rates in the 20–30 and 55 + age groups, while other age groups see a decrease, highlighting a specific cohort effect in these age brackets. For mortality, Fig. 6A shows that mortality rates increase with age, peaking in the 85–89 age group, with a gradual decline over time, reflecting improvements in treatment and survival. Figure 6B reveals a similar age-related increase in mortality, with more recent cohorts experiencing lower mortality rates at younger ages. Figure 6C demonstrates a steady decline in mortality across all age groups over time, while Fig. 6D shows that more recent birth cohorts display decreasing mortality, particularly in older populations, suggesting enhanced survival rates. These patterns underscore the dynamic nature of laryngeal cancer trends, with distinct age, period, and cohort effects, highlighting shifts in incidence and mortality, particularly in younger and older populations.

Decomposition analysis of factors influencing larynx cancer incidence and mortality in China

The decomposition analysis of factors influencing the incidence and mortality of larynx cancer in China reveals distinct contributions from aging, epidemiological changes, and population factors, with notable differences between gender groups (Fig. 7). For incidence, aging significantly increases the number of cases across all gender groups, with a higher impact observed in males compared to females (Fig. 7A). Epidemiological changes lead to a small decrease in incidence, with the reduction being more pronounced in female group. Population factors contribute to an increase in incidence, affecting both sexes similarly. The combined effect of these factors, shown by the black dots, results in a net increase in incidence for both sexes, with aging being the predominant

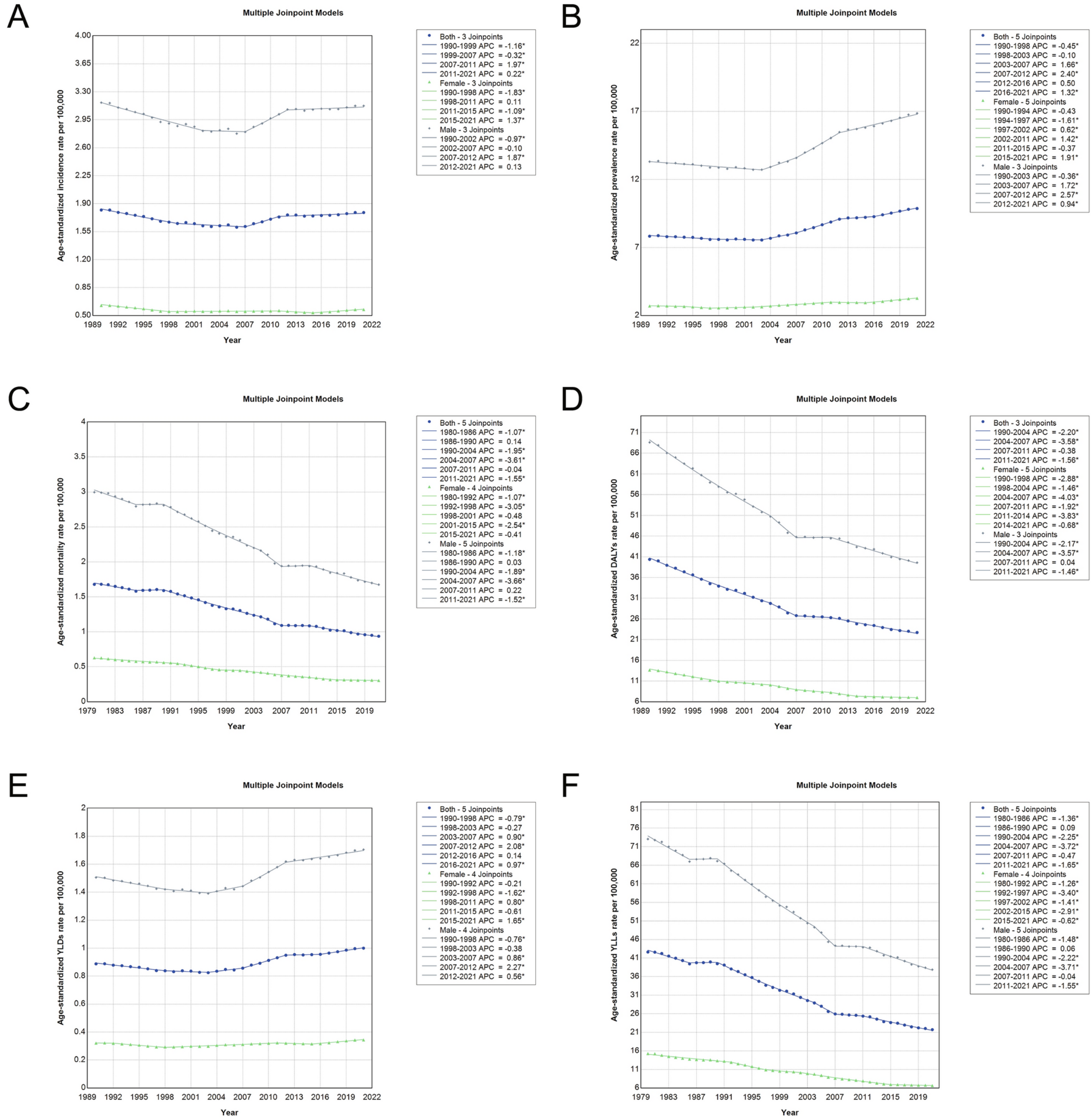

Fig. 4. Joinpoint regression analysis of ASIR, ASPR, ASMR, DALYs, YLDs, and YLLs for larynx cancer in China from 1990 to 2021. The analyses include data for both sexes (blue line), females (green line), and males (grey line), with asterisks representing statistically significant changes ($p < 0.05$). (**A**): Trends in ASIR of larynx cancer in China for both sexes, females, and males, respectively. (**B**): Trends in ASPR of larynx cancer in China for both sexes, females, and males, respectively. (**C**): Trends in ASMR of larynx cancer in China for both sexes, females, and males, respectively. (**D**): Trends in DALY rates of larynx cancer in China for both sexes, females, and males, respectively. (**E**): Trends in YLD rates of larynx cancer in China for both sexes, females, and males, respectively. (**F**): Trends in YLL rates of larynx cancer in China for both sexes, females, and males, respectively. *ASIR* age-standardized incidence rate, *ASPR* age-standardized prevalence rate, *ASMR* age-standardized mortality rate, *DALYs* disability-adjusted life years, *YLDs* years lived with disability, *YLLs* years of life lost.

contributing factor. For mortality, aging is the primary factor driving the increase, particularly among males (Fig. 7B). Epidemiological changes result in a decrease in mortality, with the reduction being more significant in the male group. Population factors also contribute to an increase in mortality, with higher impacts in the male group, while epidemiological changes contribute to reducing mortality rates. These results highlight the differential impact of aging, epidemiological changes, and population factors on larynx cancer incidence and mortality in China.

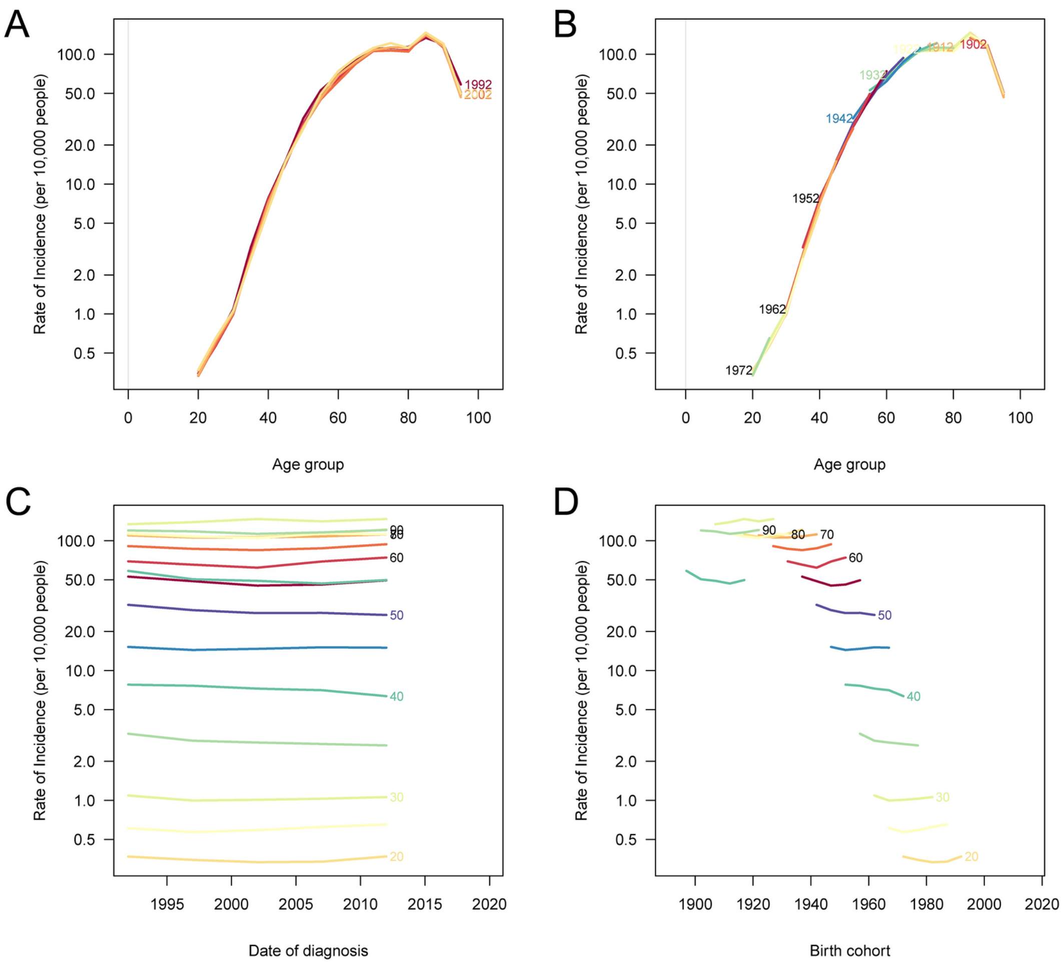

Fig. 5. Age, period, and cohort effects on the incidence of larynx cancer in China. (**A**) The ASIRs of larynx cancer according to time periods. Each line connects the ASIRs for a 5-year period. (**B**) The ASIRs of larynx cancer according to birth cohorts. Each line connects the age-specific incidence rates for a 5-year birth cohort. (**C**) The period-specific incidence rates of larynx cancer according to age groups. Each line connects the period-specific incidence rates for a 5 year age group. (**D**) The birth cohort-specific incidence rates of larynx cancer according to age groups. Each line connects the birth cohort-specific incidence rates for a 5 year age group. *ASIR* age-standardized incidence rate.

Predicted incidence rates of larynx cancer in China by 2030

The BAPC analysis predicts the incidence rates of larynx cancer in China up to the year 2030, with distinct patterns observed between gender groups (Fig. 8). For females, the predicted incidence rates show a gradual increase over the years, with a more pronounced rise observed as the timeline approaches 2030 (Fig. 8A). This suggests a continuous upward trend in larynx cancer incidence among females. For males, the predicted incidence rates exhibit a sharper increase compared to females, with a significant rise expected as the year 2030 approaches (Fig. 8B). The male incidence rates are consistently higher than those for females throughout the prediction period, indicating a greater burden of larynx cancer among males.

Discussion

The analysis of long-term trends in the burden of larynx cancer in China from 1990 to 2021 reveals significant insights into the epidemiological dynamics of the disease. Our findings indicate a steady increase in the incidence and prevalence of larynx cancer, with a particularly notable rise among males compared to females. The ASIR and ASMR for males were substantially higher than those for females, highlighting a persistent gender disparity in the burden of the disease. The decomposition analysis identified aging as the predominant factor contributing to the increasing incidence and mortality rates, while epidemiological changes showed a mitigating effect on these trends. Population growth also played a significant role in the rising burden of larynx cancer. Additionally, projections using BAPC models suggest a continuous upward trend in incidence rates up to 2030, emphasizing the need for targeted public health interventions. These findings underscore the importance of addressing risk factors such as smoking and environmental pollutants, and improving early detection and treatment strategies to manage the growing burden of larynx cancer in China.

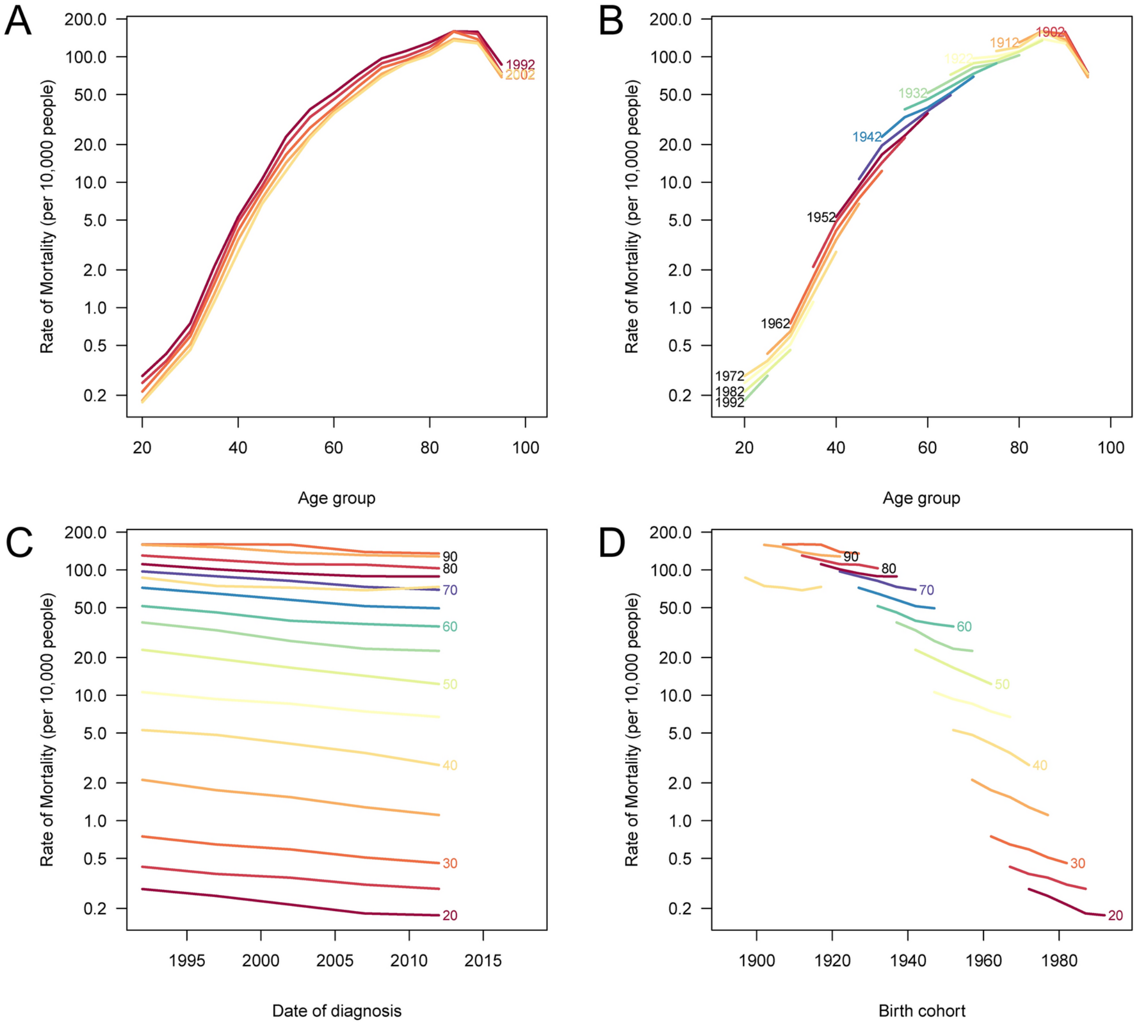

Fig. 6. Age, period, and cohort effects on the mortality of larynx cancer in China. (**A**) The ASMRs of larynx cancer according to time periods. Each line connects the ASMRs for a 5 year period. (**B**) The ASMRs of larynx cancer according to birth cohorts. Each line connects the age-specific mortality rates for a 5 year birth cohort. (**C**) The period-specific mortality rates of larynx cancer according to age groups. Each line connects the period-specific mortality rates for a 5 year age group. (**D**) The birth cohort-specific mortality rates of larynx cancer according to age groups. Each line connects the birth cohort-specific mortality rates for a 5 year age group. *ASMR* age-standardized mortality rate.

Our study's findings align with those of previous research, which has consistently shown an upward trend in larynx cancer incidence rates in East Asia, particularly in China. For instance, the GBD Study 2017 reported increases in age-standardized incidence and mortality rates for larynx cancer in East Asia, attributing these trends to factors such as rapid urbanization and lifestyle changes, including increased tobacco use[17]. Our findings are further supported by Deng et al.[6], who reported that China had one of the highest percentage increases in age-standardized incidence, DALY, and death rates for larynx cancer globally from 1990 to 2017. A stark contrast emerges when comparing larynx cancer trends in China with those observed in countries such as the United States[18] and Brazil[19], where the disease's prevalence has shown a notable decline. Rigorous studies conducted in the US and Brazil have meticulously documented this downward trajectory, crediting the decrease to a triumvirate of factors: impactful public health campaigns, enhanced regulations governing tobacco consumption, and augmented accessibility to healthcare services[18,19]. In the United States, the implementation of stringent tobacco control policies, coupled with extensive public health programs and the advent of cutting-edge medical technologies, has markedly diminished both the prevalence and incidence of larynx cancer[18]. Echoing a similar success story, Brazil's proactive stance against smoking, through comprehensive anti-tobacco initiatives and robust public health interventions, has resulted in a considerable reduction in larynx cancer diagnoses[19]. The divergence in larynx cancer trends between China and these nations underscores the differential efficacy of public health approaches and underscores the imperative for China to embrace more stringent measures aimed at curbing the escalating prevalence of the disease. This calls for a reevaluation of current strategies and the potential adoption of best practices from countries that have effectively mitigated the burden of larynx cancer.

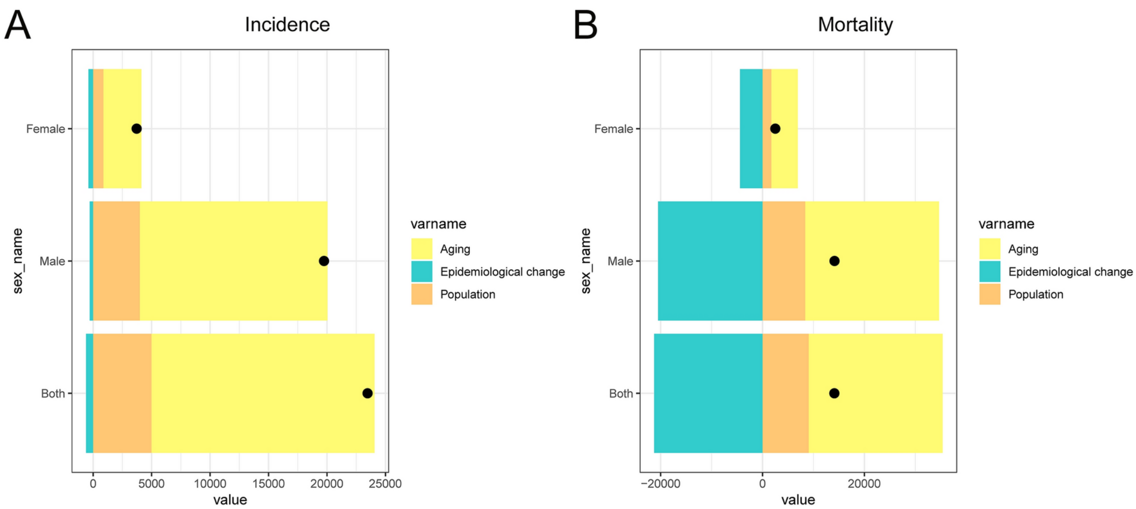

Fig. 7. Decomposition analysis of the contributions of aging, epidemiological changes, and population factors to the incidence and mortality of larynx cancer in China, stratified by gender. Positive values on the x-axis indicate an increase in incidence or mortality, while negative values indicate a decrease. The black dots represent the total impact of these three factors. (**A**) Contributions of aging, epidemiological changes, and population factors to the incidence of larynx cancer for both sexes, males, and females. (**B**) Contributions of aging, epidemiological changes, and population factors to the mortality of larynx cancer for both sexes, males, and females.

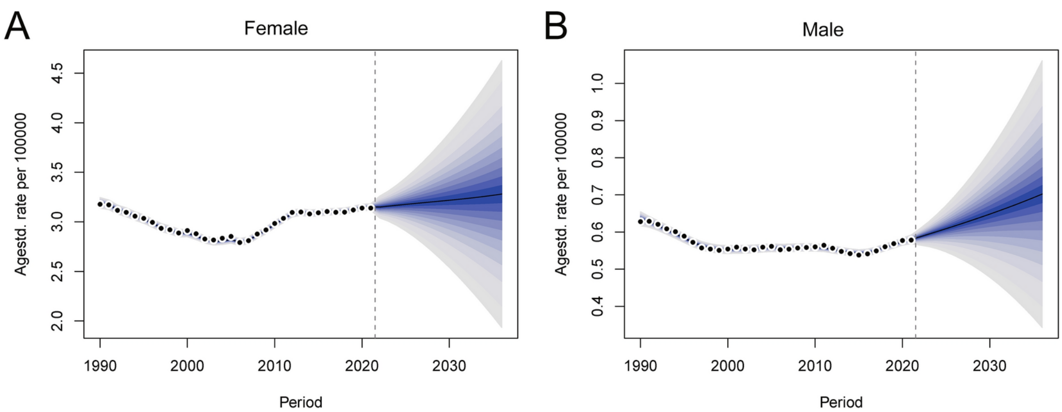

Fig. 8. BAPC analysis predicting the incidence rates of larynx cancer in China by 2030, stratified by gender. (**A**) Predicted incidence rates for females, showing the estimated rates up to the year 2030 based on BAPC analysis. (**B**) Predicted incidence rates for males, illustrating the estimated rates up to the year 2030 based on BAPC analysis. *BAPC* Bayesian age-period-cohort.

The increased incidence observed in our study can be attributed to several well-established risk factors. Tobacco smoking is the most significant risk factor, with smokers having a markedly higher risk of developing larynx cancer compared to non-smokers[7,20]. The carcinogenic effects of tobacco smoke are well-documented, and the risk increases with the duration and intensity of smoking. Alcohol consumption, particularly in combination with smoking, synergistically elevates the risk, as ethanol acts as a solvent for tobacco carcinogens, enhancing their absorption in the laryngeal mucosa[21]. Occupational exposures to carcinogens, such as asbestos, wood dust, and certain industrial chemicals, also significantly contribute to the risk of larynx cancer[22–26]. Workers in industries such as construction, metalworking, and textiles are particularly at risk due to prolonged exposure to these harmful substances. Environmental pollutants, including air pollution and secondhand smoke, further exacerbate the risk, especially in urban areas with high levels of industrial emissions. These factors highlight the need for public health measures to reduce exposure to these risk factors, particularly in high-risk groups such as males and those in certain occupations. In addition to these external factors, genetic predispositions and infections, such as human papillomavirus (HPV), have been identified as emerging risk factors. HPV-related larynx cancers tend to have a different etiology and may respond differently to treatment compared to tobacco-related cancer[20,27]. It has been noted that Chinese larynx cancer patients have a higher prevalence of HPV and that HPV infection significantly increases the risk of larynx cancer compared to larynx cancer patients outside of China[28]. Metabolic syndrome, unhealthy eating habits, lower socioeconomic status and short education are also associated with increased risk, highlighting the multifactorial nature of larynx cancer[29–33]. Addressing these diverse risk factors through comprehensive public health strategies is essential to mitigate the growing burden of larynx cancer.

Furthermore, our study provides additional insights into gender disparities, highlighting that males exhibit significantly higher incidence and mortality rates compared to females, a trend that was less emphasized in earlier studies[34]. This is consistent with the epidemiological profile of larynx cancer in Reunion Island, France[35] and Brazil[19]. The higher incidence and mortality rates among men can be attributed to several factors. Primarily, men have higher smoking and alcohol drinking rates, which is the most significant risk factor for larynx cancer[36,37]. Occupational exposures to carcinogens are also more common among men, especially in industries such as construction and manufacturing[23,38]. Occupational aspects, in particular the exposure to carcinogenic agents, explain a large portion of the association between low educational level and larynx cancer risk among males[39,40]. It has been reported in peer-reviewed literature that asbestos-exposed male workers are at greater risk for larynx cancer-related deaths[24]. Moreover, cultural and lifestyle factors may contribute to higher alcohol consumption rates among men, further increasing their risk[23]. These differences highlight the need for gender-specific public health interventions to address these risk factors effectively. Future studies should focus on understanding the underlying reasons for these gender disparities and developing targeted strategies to reduce the burden of larynx cancer among men.

Our decomposition analysis revealed that aging was the primary driver of increasing larynx cancer incidence and mortality rates. As the population ages, the risk of developing larynx cancer naturally increases due to the accumulation of genetic mutations and longer exposure to risk factors such as smoking and environmental pollutants. This finding is consistent with the results of previous studies[34,41–43]. Additionally, epidemiological changes, including improvements in healthcare and early detection, have shown a mitigating effect on the mortality rates, despite the rising incidence. The reduction in mortality can be attributed to better treatment options and early diagnosis, which have improved survival rates for larynx cancer patients[44,45]. However, the increase in incidence rates due to population growth and aging necessitates continued efforts in public health interventions focused on prevention, early detection, and effective treatment. The joinpoint analysis in our study identified several key time points where significant changes in incidence and mortality trends occurred. Notably, the most substantial increases in incidence rates were observed during periods of rapid urbanization and economic growth in China. For example, from 2000 to 2010, China experienced accelerated urbanization, leading to increased exposure to risk factors such as tobacco and environmental pollutants[46,47]. This period coincides with a marked rise in the incidence of larynx cancer, as documented in our joinpoint analysis. Additionally, improvements in diagnostic techniques and healthcare access during this time may have contributed to the observed increase in incidence rates. Another significant turning point identified was around 2015, where a stabilization or slight decrease in incidence rates was noted. This could be attributed to the implementation of stricter tobacco control policies and heightened public awareness of the health risks associated with smoking and environmental pollutants[48]. The joinpoint analysis underscores the importance of monitoring temporal trends and implementing timely public health interventions to address the evolving risk factors for larynx cancer.

Despite the comprehensive nature of this study, several limitations must be acknowledged. The accuracy and completeness of the data from the GBD Study may vary, potentially affecting the reliability of our findings[10]. Additionally, the study did not account for all possible risk factors, such as genetic predispositions and specific occupational exposures, which could influence the trends in larynx cancer incidence and mortality. The BAPC models and joinpoint regression analyses rely on assumptions that may oversimplify cancer trends. Specifically, they assume that the effects of age, period, and cohort on cancer incidence and mortality are additive and independent, which may not fully account for potential interactions between these factors. Moreover, these models assume that changes in cancer trends occur in a smooth, continuous manner, potentially overlooking abrupt shifts caused by external factors such as policy changes, environmental influences, or medical advancements. These limitations could lead to an incomplete representation of the multifactorial nature of cancer trends. Variations in healthcare access and quality across different regions in China were not thoroughly examined, which could impact early detection and treatment outcomes. To address these limitations, future research should consider incorporating more granular data on genetic and environmental risk factors to provide a more comprehensive understanding of larynx cancer trends. Additionally, longitudinal studies examining the impact of healthcare access and quality on cancer outcomes would be beneficial. It is also crucial to develop targeted public health interventions that focus on high-risk populations, such as males and the elderly, and to continue improving early detection and treatment strategies. Integrating these approaches will help mitigate the rising burden of larynx cancer and improve overall survival rates in China.

Conclusions

This study provides a comprehensive analysis of the long-term trends in the burden of larynx cancer in China, offering crucial insights for public health planning and policy formulation. The findings underscore the critical need for targeted interventions to address the rising incidence and prevalence rates, particularly among high-risk groups such as males and the elderly. Future research should focus on incorporating more granular data on genetic and environmental risk factors to enhance our understanding of the disease's etiology. Additionally, longitudinal studies examining the impact of healthcare access and quality on cancer outcomes are essential. Developing and implementing effective public health strategies, such as smoking cessation programs, reducing exposure to environmental pollutants, and improving early detection and treatment facilities, are paramount to mitigating the rising trends in larynx cancer. Continued efforts in these areas will be vital in reducing the burden of larynx cancer and improving overall survival rates in China.

Data availability

Data for this study are accessible via the Institute for Health Metrics and Evaluation (IHME)'s online platform, found at https://vizhub.healthdata.org/gbd-results/.

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References

1. Bray, F. et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J. Clinicians* **74** (3), 229–263 (2024).
2. Ramsey, T. et al. Laryngeal cancer: Global socioeconomic trends in disease burden and smoking habits. *Laryngoscope* **128** (9), 2039–2053 (2018).
3. Nocini, R., Molteni, G., Mattiuzzi, C. & Lippi, G. Updates on larynx cancer epidemiology. *Ch. J. Cancer Res.* **32** (1), 18–25 (2020).
4. Shen, Z., Li, J., Luo, L. & Han, L. The global, regional, and national burden of laryngeal cancer and the attributable risk factors in all countries and territories during 2007–2017. *Front. Biosci.* **26** (11), 1097–1105 (2021).
5. GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet (Lond. England)* **392**(10159), 1923–1994 (2018).https://doi.org/10.1016/S0140-6736(18)32225-6 Erratum in: Lancet. 2019 Jan12;393(10167):132. https://doi.org/10.1016/S0140-6736(18)33216-1. Erratum in: Lancet. 2019 Jun 22;393(10190):e44. https://doi.org/10.1016/S0140-6736(19)31429-1. PMID: 30496105; PMCID: PMC6227755
6. Deng, Y. et al. Global burden of larynx cancer, 1990–2017: estimates from the global burden of disease 2017 study. *Aging* **12** (3), 2545–2583 (2020).
7. Ye, E. et al. Trend and projection of larynx cancer incidence and mortality in China from 1990 to 2044: A Bayesian age-period-cohort modeling study. *Cancer Med.* **12** (15), 16517–16530 (2023).
8. GBD 2021 Risk Factors Collaborators. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet (London, England)*, **403**(10440), 2162–2203 (2024). https://doi.org/10.1016/S0140-6736(24)00933-4. Erratum in: Lancet.2024 Jul 20;404(10449):244. https://doi.org/10.1016/S0140-6736(24)01458-2. PMID: 38762324; PMCID: PMC11120204
9. GBD 2021 Demographics Collaborators. Global age-sex-specific mortality, life expectancy, and population estimates in 204 countries and territories and 811 subnational locations, 1950-2021, and the impact of the COVID-19 pandemic: a comprehensive demographic analysis for the Global Burden of Disease Study 2021. *Lancet (London, England)* 403(10440):1989-2056 (2024). https://doi.org/10.1016/S0140-6736(24)00476-8. Epub 2024 Mar 11. PMID: 38484753;PMCID: PMC11126395
10. GBD 2021 Causes of Death Collaborators. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet (London, England)*, **403**(10440), 2100–2132 (2024). https://doi.org/10.1016/S0140-6736(24)00367-2. Epub 2024 Apr 3. Erratum in: Lancet. 2024 May 18;403(10440):1988. https://doi.org/10.1016/S0140-6736(24)00824-9. PMID: 38582094; PMCID: PMC11126520.
11. Kim, H. J., Fay, M. P., Feuer, E. J. & Midthune, D. N. Permutation tests for joinpoint regression with applications to cancer rates. *Stat. Med.* **19** (3), 335–351 (2000).
12. Kim, H. J., Chen, H. S., Byrne, J., Wheeler, B. & Feuer, E. J. Twenty years since Joinpoint 1.0: Two major enhancements. their justification, and impact. *Stat. Med.* **41** (16), 3102–3130 (2022).
13. Tu, Y. K., Krämer, N. & Lee, W. C. Addressing the identification problem in age-period-cohort analysis: a tutorial on the use of partial least squares and principal components analysis. *Epidemiology (Cambridge, Mass)* **23** (4), 583–593 (2012).
14. Zhang, Y. et al. Long-term trends in the burden of inflammatory bowel disease in China over three decades: A joinpoint regression and age-period-cohort analysis based on GBD. *Front Public Health* **2022**, 10 (2019).
15. Han, T., Chen, W., Qiu, X. & Wang, W. Epidemiology of gout–Global burden of disease research from 1990 to 2019 and future trend predictions. *Ther. Adv. Endocrinol. Metab.* **15**, 20420188241227296 (2024).
16. GBD 2019 Dementia Forecasting Collaborators. Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: an analysis for the Global Burden of Disease Study 2019. *The Lancet Public health* 7(2): e105–e125 (2022). https://doi.org/10.1016/S2468-2667(21)00249-8. Epub 2022 Jan 6. PMID: 34998485; PMCID: PMC8810394.
17. Shen, Z., Li, J., Luo, L. & Han, L. The global, regional, and national burden of laryngeal cancer and the attributable risk factors in all countries and territories during 2007–2017. *Front. Biosci. Landmark* **26** (11), 1097–1105 (2021).
18. Divakar, P. & Davies, L. Trends in incidence and mortality of larynx cancer in the US. *JAMA Otolaryngol. Head Neck Surg.* **149** (1), 34–41 (2023).
19. Viana, L. P. et al. Trend of the burden of larynx cancer in Brazil, 1990 to 2019. *Revista Sociedade Brasileira Med. Tropical* **55** (1), e0269 (2022).
20. Liberale, C., Soloperto, D., Marchioni, A., Monzani, D. & Sacchetto, L. Updates on larynx cancer: Risk factors and oncogenesis. *Int. J. Mol. Sci.* **24** (16), 12913 (2023).
21. Menvielle, G. et al. The joint effect of asbestos exposure, tobacco smoking and alcohol drinking on laryngeal cancer risk: evidence from the French population-based case-control study ICARE. *Occup. Environ. Med.* **73** (1), 28–33 (2016).
22. Clin, B. et al. Head and neck cancer and asbestos exposure. *Occup. Environ. Med.* **79** (10), 690–696 (2022).
23. Bayer, O. et al. Occupation and cancer of the larynx: a systematic review and meta-analysis. *Eur. Arch. Oto-Rhino-Laryngol.* **273** (1), 9–20 (2016).
24. Peng, W. J., Mi, J. & Jiang, Y. H. Asbestos exposure and laryngeal cancer mortality. *Laryngoscope* **126** (5), 1169–1174 (2016).
25. Ferster, A. P. O., Schubart, J., Kim, Y. & Goldenberg, D. Association between laryngeal cancer and asbestos exposure: A systematic review. *JAMA Otolaryngol. Head Neck Surg.* **143** (4), 409–416 (2017).
26. Wronkiewicz, S. K. et al. Chrysotile fibers in tissue adjacent to laryngeal squamous cell carcinoma in cases with a history of occupational asbestos exposure. *Modern Pathol.* **33** (2), 228–234 (2020).
27. Tong, F. et al. Prevalence and prognostic significance of HPV in laryngeal squamous cell carcinoma in Northeast China. *Cell. Physiol. Biochem. Int. J. Exp. Cell. Physiol. Biochem. Pharmacol.* **49** (1), 206–216 (2018).
28. Zhang, C., Deng, Z., Chen, Y., Suzuki, M. & Xie, M. Is there a higher prevalence of human papillomavirus infection in Chinese laryngeal cancer patients? A systematic review and meta-analysis. *European Arch. Oto-Rhino-Laryngol.* **273** (2), 295–303 (2016).
29. Kim, S. Y., Han, K. D. & Joo, Y. H. Metabolic syndrome and incidence of laryngeal cancer: A nationwide cohort study. *Sci. Rep.* **9** (1), 667 (2019).
30. Kim, H. B., Kim, G. J., Han, K. D. & Joo, Y. H. Changes in metabolic syndrome status and risk of laryngeal cancer: A nationwide cohort study. *PLoS One* **16** (6), e0252872 (2021).
31. Qi, H. et al. Epidemiological analysis of 1234 cases of laryngeal cancer in Shanxi Province, China. *Cancer Control J. Moffitt Cancer Center* **28**, 10732748211041236 (2021).
32. de la Cour, C. D., Munk, C., Aalborg, G. L. & Kjaer, S. K. Base of tongue/tonsillar and laryngeal cancer in Denmark 1994–2018: Temporal trends in incidence according to education and age. *Oral Oncol.* **128**, 105832 (2022).

33. Vlastarakos, P. V. et al. Dietary consumption patterns and laryngeal cancer risk. *Ear Nose Throat J.* **95** (6), E32-38 (2016).
34. Charvat, H. & Saito, E. Age-specific larynx cancer incidence rate in the world. *Japan. J. Clin. Oncol.* **51** (7), 1181–1182 (2021).
35. Delagranda, A. et al. Epidemiological features of cancers of the oral cavity, oropharynx, hypopharynx and larynx cancer in Réunion Island. *Eur. Ann. Otorhinolaryngol. Head Neck Dis.* **135** (3), 175–181 (2018).
36. Huang, J. et al. Updated disease distributions, risk factors, and trends of laryngeal cancer: a global analysis of cancer registries. *Int. J. Surg. (London, England)* **110** (2), 810–819 (2024).
37. Di Credico, G. et al. Alcohol drinking and head and neck cancer risk: the joint effect of intensity and duration. *Br. J. Cancer* **123** (9), 1456–1463 (2020).
38. Barul, C. et al. Welding and the risk of head and neck cancer: the ICARE study. *Occup. Environ. Med.* **77** (5), 293–300 (2020).
39. Santi, I., Kroll, L. E., Dietz, A., Becher, H. & Ramroth, H. To what degree is the association between educational inequality and laryngeal cancer explained by smoking, alcohol consumption, and occupational exposure?. *Scand. J. Work Environ. Health* **40** (3), 315–322 (2014).
40. Barul, C. et al. Occupational exposure to petroleum-based and oxygenated solvents and hypopharyngeal and laryngeal cancer in France: the ICARE study. *BMC Cancer* **18** (1), 388 (2018).
41. Ju, W. et al. Cancer statistics in Chinese older people, 2022: current burden, time trends, and comparisons with the US, Japan, and the Republic of Korea. *Sci. China Life Sci.* **66** (5), 1079–1091 (2023).
42. Tsoi, K. K., Hirai, H. W., Chan, F. C., Griffiths, S. & Sung, J. J. Cancer burden with ageing population in urban regions in China: projection on cancer registry data from world health organization. *Br. Med. Bull.* **121** (1), 83–94 (2017).
43. Li, X. et al. The primary health-care system in China. *Lancet (London, England)* **390** (10112), 2584–2594 (2017).
44. Steuer, C. E., El-Deiry, M., Parks, J. R., Higgins, K. A. & Saba, N. F. An update on larynx cancer. *CA Cancer J. Clin.* **67** (1), 31–50 (2017).
45. García Lorenzo, J. et al. Modifications in the treatment of advanced laryngeal cancer throughout the last 30 years. *Eur. Arch. Oto-Rhino-Laryngol.* **274** (9), 3449–3455 (2017).
46. Liu, M., Liu, X., Huang, Y., Ma, Z. & Bi, J. Epidemic transition of environmental health risk during China's urbanization. *Sci. Bull.* **62** (2), 92–98 (2017).
47. Yuan, J. et al. Urbanization, rural development and environmental health in China. *Environ. Dev.* **28**, 101–110 (2018).
48. Chan, K. H., Xiao, D., Zhou, M., Peto, R. & Chen, Z. Tobacco control in China. *Lancet Public Health* **8** (12), e1006–e1015 (2023).

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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