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Background

Currently, tracheal, bronchial, and lung (TBL) cancer remains the highest in terms of global incidence and mortality rates among all types of cancers [1]. In 2022, tracheal, bronchial, and lung cancer (TBL) ranked as the most prevalent malignancy, accounting for approximately 2,480,675 newly diagnosed cases, which represented 12.4% of all global cancer cases. Furthermore, TBL cancer was the leading cause of cancer mortality, with an estimated 1,817,469 fatalities, constituting 18.7% of total global cancer-related deaths [2, 3]. is underscores the substantial burden TBL imposes on global public health [4].

e World Health Organization (WHO) revised its global air quality guidelines in 2021, stipulating that the annual mean concentration of particulate matter (PM) $PM_{2.5}$ should not surpass 5 $\mu g/m^3$ [5]. Particulate matter pollution primarily encompasses household particulate matter air pollution and ambient Particulate matter air pollution [6]. Recently conducted studies have underscored the significance of ambient particulate matter pollution as a substantial contributor to TBL development, in addition to conventional risk factors like smoking [7–9]. e data shows that the attributable DALYs due to ambient ambient ozone pollution and particulate matter pollution increased, from 2000 to 2021 [10]. However, the prevalence and impact of ambient particulate matter pollution vary widely across regions and populations [11]. Understanding the latest trends and burdens associated with ambient particulate matter pollution is crucial for reducing the overall burden of TBL cancer.

In this study, we aims to assess the changes of TBL cancer attributable to ambient particulate matter pollution by the age-standardized disability-adjusted life year rate (ASDR) of TBL cancer from 1990 to 2021 in 204 countries and territories, stratifying the data by age, sex, region, country, and socio demographic index (SDI) based on the latest data from the GBD 2021 study, o ering insightful guidance for medical agencies, policymakers, and the general public.

Materials and methods

Data collection

All the data in this study were obtained for free access from the Global Health Data 2021 (https://ghdx.healthdata.org/gbd-2021/sources), which is the largest and most recent assessment of the burden of 371 diseases and injuries and 88 risk factors in 204 countries or territories form 1990 to 2021 [12]. e burden of disease encompasses the overall socioeconomic and health impacts, leading to poor health, disability, and premature mortality. TBL cancer, succinctly defined as tumors within the trachea, bronchus, or lung, is classified in the International Classification of Diseases (ICD) 10 by codes C33 and C34-C34.92and in the ICD9 by codes 162–162.9, 209.21, V10.1-V10.20, V16.1-V16.2,and V16.4-V16.40 [13]. e International Classification of Diseases, Revision 10 (ICD-10), is the current diagnostic standard and contains the most exhaustive cause list. We extracted the data of incident patients, prevalent patients, deaths, and DALYs and calculated the incidence, prevalence, mortality, and DALYs rates of TBL caner due to ambient particulate matter pollution from 1990 to 2021.

Signi□cant de□nitions

e socio-demographic index(SDI) is a comprehensive indicator introduced by the Institute for Health Metrics and Evaluation (IHME) in 2015, which can assess the social and economic conditions that a ect health outcomes in di erent development level of countries or regions. SDI is the geometric mean of indices ranging from 0 to 1 of total fertility rate (TFR) for those younger than 25 years old(TFU25), the mean education level for those aged 15 years old and above (EDU15 +), and lag-distributed income (LDI) per-capita. In the GBD 2021 study, after computing SDI, the final values were multiplied by 100 to create a scale ranging from 0(the worst) to 100(the best) [13]. e value 0 indicates the lowest income and the minimum years of education, and the highest fertility, Conversely, the value 100 indicates the highest income and the most years of education and the lowest fertility. In the GBD 2021, e 204 countries and territories were stratified into five SDI groups: low(≤ 0.454743), low-middle (0.454743–0.607679), middle (0.607679–0.689504), high-middle(0.689504–0.805129), and high SDI(> 0.805129) [14].

Disability-adjusted life years (DALYs), a standard metric for quantifying burden, represent the total years of healthy life lost from the onset of a disease to death, encompassing both years of life lost (YLLs) and years lived with disability (YLDs), as expressed by the formula [15]:

$$\text{DALYs} =$$

Age-standardized rates were used to evaluate and compare the incidence, prevalence, deaths, and DALYs rates among nations or regions with distinct age structures and demographic characteristics.

e estimated annual percentage change (EAPC) [16] is a widely and e ective used indicator which has been extensively utilized in other studies to track the trends of indicators such as prevalence, DALYs and incidence rates during specifc time periods, as expressed by the formula: $\ln(y) = \alpha + \beta x + \varepsilon$, the y is mortality (ASMR) or disability-adjusted life years (ASDR), and x is the calendar year.

EAPC and its 95% confidence interval (CI) is calculated as expressed by the formula:$100 \times (\exp(\beta) - 1)$ [17]. If the 95% CI of corresponding EAPC estimation > 0, ASDR was recognized to be in an increasing trend, on the contrary, if 95% CI of corresponding EAPC estimation < 0, ASDR was recognized to be a decreasing trend, but if the 95% CI of corresponding EAPC including 0, ASDR was recognized to be stable.

Statistics

We utilized decomposition analysis to study the change of DALYs in TBL cancer due to ambient particulate matter pollution from 1990 to 2021, by three population-level drivers: population aging, population growth, and epidemiologic changes (epidemiologic changes is age-and population-standardized rates) to allow the quantification of the e ect of each factor on the total change [18].

Smoothing spline models were fitted to determine the shapes of the correlations between age-standardized rates and the SDI. ese models produced estimates of the average age-standardized rates expected for every level of SDI.

In this study, all count and rates are presented with 95% uncertainty intervals (UIs) [19] (generated using the 2.5th and 97.5th percentile ordered 1000 draws of the posterior distribution). All the rates are reported per 100,000 population. R software (R core team, version 4.0.2, Vienna, Austria) conducted all data.

Results

Burden of TBL cancer due to ambient particulate matter pollution to global

As shown in Table 1, the EAPC ASDR of Global due to ambient particulate matter pollution was 0.2[95% UI 0.1 to 0.3], representing the ASDR per 100,000 population increased by 0.2% to 79.6[95% UI 49.0 to 111.2]. It was worth watching that the EAPC ASDR of male due to ambient particulate matter pollution was -0.2[95% UI -0.3 to 0.0].

e highest ASDR was in China (190.9 [95% UI, 110.0 to 274.3]), whereas the lowest was in Africa Malawi (2.2 [95% UI,1.1 to 3.7] in 2021; Fig. 1. ere was more than 75-fold considerable global variation in ASDR among 204 countries. e trends of ASDR varied considerably among 204 countries, with the largest increase in Equatorial Guinea(EAPC 6.0[95% UI, 5.1 to 6.9]) and the largest decrease in the Estonia(EAPC -6.4[95% UI,-6.8 to -6.0]).

Age and sex patterns

As shown in Fig. 2, the distribution of pattern was in a similar manner in male, female and both. e ASDR gradually increased with age (from 25 years old to 69 years old), with the highest value at the 65–69 years and followed by a gradual decline with age (from 70 years old to 95 + years old). As shown in Fig. 3, the temporal patterns of distribution were similar for both and male, the ASDR gradually descended from 1990 to around 1998, slowly increased and reached the peak in around 2014, then declined gradually until a turning point in 2020. For female, the pattern was steadily ascending from 1990 to 2014, culminating in its peak in 2014, followed by a gradual decline until it reaches an inflection point in 2020.

Disease burden by socio demographic Index

As shown in Fig. 4, the temporal trends of ASDR was gradual decline from 1990 to 2021 in the high SDI. ere were some small fluctuations at the beginning, but it gradually increase from 2000, peaked around 2014, and then gradually declined again, with an upward trend starting from 2020 in High middle SDI. e trends of Middle SDI was similar to the High middle SDI. e trends were remained stable with slight increase changes in Low-middle SDI and Low SDI.

Burden trends associated with the SDI

In 2021, there was a positive correlation between ASDR of TBL cancer attributable to particulate matter pollution and the SDI. With the improvement of the economy, the overall burden is on the rise. e ASDR increased with SDI, but decreased substantially at higher SDI levels (Fig. 5). Across 21 regions, the burden of TBL cancer due to particulate matter pollution remains the trend of steady rise when the SDI value less than 0.7. When the SDI value was around 0.7, the burden of TBL cancer due to particulate matter pollution reached its peak, therewith most rapid declined in the high SDI. East Asia and Central Europe exhibited higher observed values than the

Table 1 The global ASDR of TBL cancer due to particulate matter pollution in 1990 and 2021 and percentage change by sex from 1990 to 2021

ASDR age-standardized DALY rate, *no.* number, *DALYs*

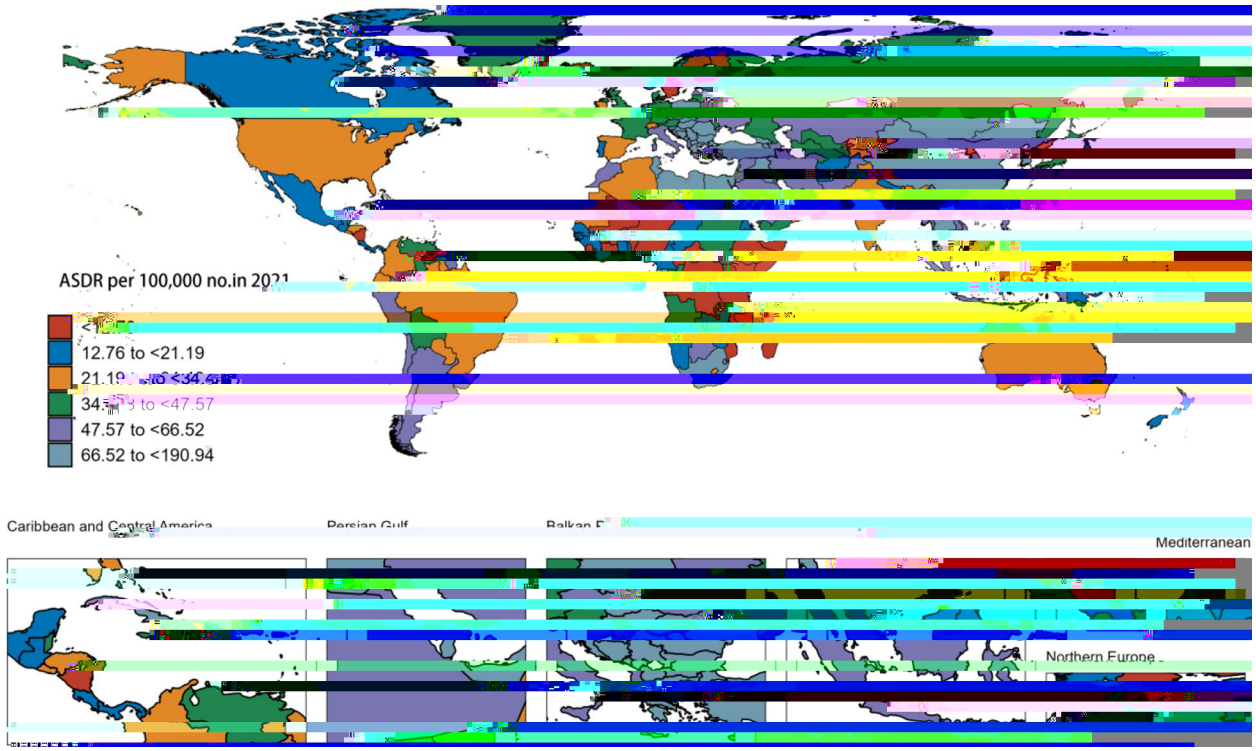

Fig. 1 Worldwide burden of TBL cancer due to particulate matter pollution in 2021. The ASDR per 100,000 population of TBL cancer due to particulate matter pollution in 204 countries and territories in 2021

fitted curves, while such as Austraiasia, South Asia and Western Sub-Saharan Africa had a lower observed values than the fitted curves.

Decomposition analysis of change in DALYs

e Table 2 and Fig. 6 show the results of decomposition analysis in DALYS attributable to three population-level determinants, include aging, growth, and epidemiologic change, at the global level and five SDI. Globally, 80% of the DALYs increase was attributed to population growth, followed by population aging (24%) and epidemiologic changes (-4%). e contribution of population growth to the overall DALYs change was the most pronounced in the Low SDI quintile (84%), followed by the High-middle SDI (64%), Low-middle SDI (53%), Middle SDI (42%), and high SDI (42%). e contribution of population aging(24%) was more than the epidemiological Change(-4%) to the overall DALYs change at Global. But the contribution of epidemiological change to the overall DALYs change at Low-middle SDI(40%) and Middle SDI(39%) were significant. whereas epidemiological change played a relatively weak role in the High-middle SDI (4%), and nearly vanished in Global (-4%). e contribution of aging to the overall DALYs change played a significant role at High-middle SDI(32%) and Middle SDI(19%), but played a relatively weak role in Low-middle SDI(7%) and Low SDI(5%).

Discussion

Most of previous GBD analyses have focused on the burden of TBL cancer globally, or in specific regions, while analyses on the TBL cancer burden attributable to specific risk factors are often infrequent. is study will be the first to assess the burden of TBL cancer attributable to particulate matter pollution using data from the post COVID-19 pandemic period. is study used the latest GBD 2021 data to summarize the epidemiological characteristics of the global burden of TBL cancer attributable to particulate matter pollution, included comparisons between di erent regions, countries, and age groups.

e results showed that the absolute burden of TBL cancer attributable to particulate matter pollution had been increasing globally, of which males, middle-aged and elderly individuals were the high-risk groups. Moreover showed a strong association with SDI. e High-middle SDI region, East Asia and Central Europe exhibited higher observed values than the fitted curves. e highest ASDR was in China. China exhibited the highest TBL cancer burden attributable to particulate matter pollution. e burden of TBL cancer due to particulate matter pollution reached its peak, when the SDI value was 0.7,

therewith most rapid declined in the high SDI. Decompo-

various lockdown measures in each country was contingent upon the severity of the COVID-19 pandemic. Notably, there was a significant reduction observed in the concentrations of major air pollutants, particularly particulate matterand nitrogen dioxide (NO_2), across all countries [26]. e disease burden of TBL cancer attributable to particulate matter pollution has significantly increased from 1990 to 2021, albeit with minor fluctuations.

e variation in SDI levels across di erent areas in this study can be attributed to the disparity in pollution levels within these regions. According to a study, approximately 7.3 billion individuals worldwide are exposed to annual average $PM_{2.5}$ concentrations that do not meet safety standards, with approximately 80% residing in low- and middle-income countries such as China, India, and Sub(P)11ith ahina(al)- Tw(t)6ub(P)

accelerated industrialization and urbanization, which often results in heightened levels of pollutant emissions [29].

Conclusions

is study provided a comprehensive estimate the global TBL cancer burden. e disease burden of TBL cancer attributable to ambient particulate matter pollution has increased, especially in regions and countries with High-middle SDI. e findings of this study can serve as a foundation for the development of relevant policies and the e cient allocation of limited resources.

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