Am J Cancer Res 2025;15(11):4727-4736
www.ajcr.us /ISSN:2156-6976/ajcr0168295

Original Article

Trends and projections of smoking-attributable lung cancer burden among the elderly in China, 1990-2021

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Received August 22, 2025; Accepted November 6, 2025; Epub November 15, 2025; Published November 30, 2025

Abstract: This study retrospectively analyzed trends in smoking-attributable lung cancer burden among Chinese adults aged 65 years and above from 1990 to 2021 and projected future trends from 2021 to 2050. Data on deaths and disability-adjusted life years (DALYs) were extracted from the Global Burden of Disease Study (GBD 2021). Statistical analysis was performed using R software (4.1.3) to estimate estimated annual percentage changes (EAPC) in disease burden trends. A Bayesian age-period-cohort (BAPC) model was applied to forecast smoking-attributable lung cancer burden from 2021 to 2050. From 1990 to 2021, the burden of lung cancer attributable to smoking among older adults in China showed an upward trend, in contrast to the global decline. The DALY rate increased from 2,948.7 to 3,384.46 per 100,000 population (EAPC = 0.62%, 95% CI: 0.4%, 0.85%), while the mortality rate rose from 150.12 to 186.36 per 100,000 population (EAPC = 0.93%, 95% CI: 0.67%, 1.19%). Both DALY and mortality rates increased across all age groups (65-69, 70-74, 75-79, 80-84, and ≥85 years), with males exhibiting significantly higher burden levels and growth rates than females. Projections indicate that between 2021 and 2050, both the absolute number of DALYs and deaths from smoking-attributable lung cancer in this population will continue to rise, and their share of the total national burden will progressively increase. In conclusion, the smoking-attributable lung cancer burden among elderly Chinese adults has risen continuously since 1990 and is expected to grow further. Strengthened tobacco control policies, targeted public health interventions, and enhanced early screening among high-risk groups, including the elderly and women, are urgently needed to mitigate this growing burden.

Keywords: Elderly, smoking, lung cancer, dalys, mortality, disease burden projection

Introduction

Lung cancer is one of the most common malignancies worldwide and remains the leading cause of cancer-related deaths in most countries [1]. According to the latest estimates from the International Agency for Research on Cancer (IARC) [2], lung cancer was the most in most countries cancer in 2022, accounting for approximately 12.4% of the nearly 20 million new cancer cases, reaching nearly 2.5 million cases. Among 9.7 million cancer deaths, approximately 1.8 million (18.7%) were attributed to lung cancer. In China, lung cancer ranks first in both incidence and mortality among all malignancies. According to data jointly calculated by the National Cancer Centre of China and IARC in 2024 [3, 4], approximately 4.82 million new cancer cases were reported in 2022, including 1.06 million new lung cancer cases (21.98%); the number of cancer-related deaths was approximately 2.5742 million, of which about 733,300 deaths were attributed to lung cancer (28.49%). These figures indicate that both the incidence and mortality of lung cancer have continued to rise compared with 2015, high-

https://doi.org/10.62347/BTGY5504

lighting a substantial and increasing disease burden in China.

Lung cancer also ranks first in cancer-related disability-adjusted life years (DALYs) among the elderly population in China [5]. Extensive epidemiological and experimental studies, both domestically and internationally, have confirmed that long-term smoking is the most significant risk factor for the development of lung cancer, and the risk increases with smoking duration, particularly among elderly population [6, 7]. However, there are relatively few studies in China examining long-term trends and projections of smoking-attributable lung cancer burden among the elderly population.

Using the latest Global Burden of Disease 2021 (GBD 2021) dataset, this study comprehensively analyzed the smoking-attributable lung cancer burden among the elderly population aged 65 and above in China and globally from 1990 to 2021, and projected future trends to 2050. Through this analysis, we aim to reveal the trend of smoking-related lung cancer burden in the elderly population and provide evidence-based insights to support the early implementation of targeted interventions.

Methods

Sources of data

Data for this study were obtained from the GBD 2021 database (https://www.healthdata.org/research-analysis/gbd), which provided information on the incidence, mortality, DALYs, and various risk factors for 371 diseases and injuries across different genders and age groups in 204 countries and regions from 1990 to 2021. The GBD 2021 project was conducted by the Institute for Health Metrics and Evaluation (IHME). In this study, we selected “China” and “Global” as the location, “lung cancer” as the cause, and “death”, “incidence”, and “disability-adjusted life-years (DALY)” as outcome indicators. The Global Health Data Exchange query tool was used to extract disease burden data associated with lung cancer. We collected data on risk factors and disease burden for lung cancer attributable to smoking among individuals aged 65 and older in both the global and Chinese populations, stratified by gender and age, from 1990 to 2021. The percentage changes in these measures from 1990 to 2021 were used to assess temporal trends in the smoking-attributable lung cancer burden.

Analysis of estimated annual percentage change (EAPC), deaths and DALYs in patients with lung cancer

Descriptive analyses were conducted on the incidences, deaths and DALY data stratified by age and sex. The population was categorized into five age groups (65-69, 70-74, 75-79, 80-84, and ≥85 years) to describe age-related incidences, mortality, and DALY rates of lung cancer in 1990, 2000, 2010 and 2021. Detailed methods for the calculation of deaths and DALYs are available in previous studies [8]. To evaluate temporal trends in the lung cancer burden, the EAPC and its 95% confidence interval (CI) were calculated [9]. The EAPC quantifies the average annual rate of change over a specified time period, indicating whether disease indicators increased or decreased over time. When both the EAPC and its 95% CI were greater than 0, the indicator was considered to have an increasing trend; conversely, values below 0 indicated a decreasing trend.

In addition, this study used actual disease burden data on smoking-attributable lung cancer among the elderly population in China from 1990 to 2021 to project future trends in smoking-related lung cancer mortality, mortality rates, DALYs, and other related disease burden indicators from 2022 to 2050.

Statistical analysis

Trend analysis was performed using the Bayesian Age-Period-Cohort (BAPC) model, a regression-based predictive model that incorporates age, period, and cohort effects [10]. By introducing Bayesian inference, this model enhances the precision of long-term disease burden projections. A two-sided P value <0.05 was considered statistically significant. All analyses were conducted using R software version 4.1.3.

Results

Trends in the disease burden of smoking-attributable lung cancer among the elderly population aged ≥65 years in China (1990-2021)

From 1990 to 2021, the disease burden of lung cancer attributable to smoking among Chinese

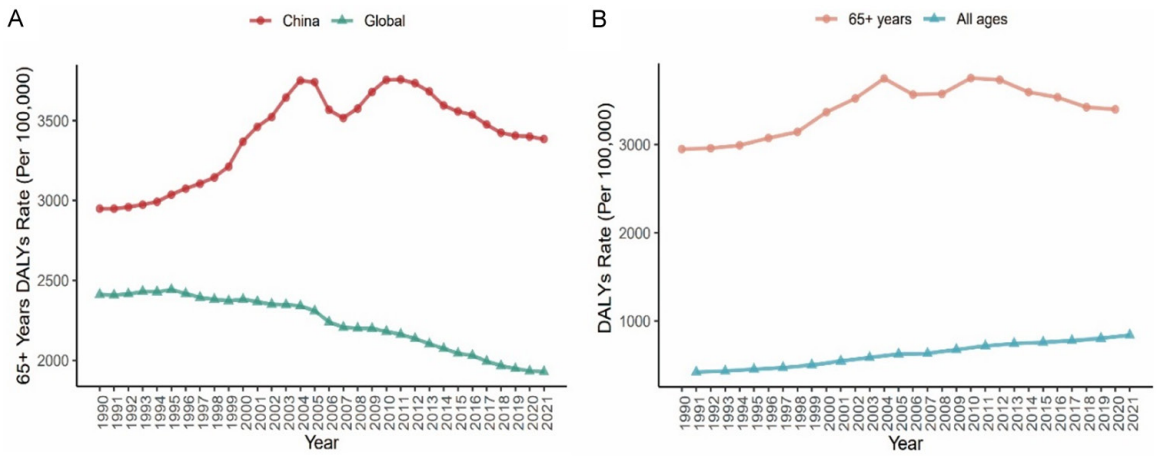

Figure 1. The trends in smoking-attributable lung cancer burden in China and Globally (1990-2021). A: Comparison of DALY rate in elderly aged ≥65 years between China and Global. B: Comparison of DALY rate between Chinese elderly and all ages.

Table 1. *Trends in* smoking-attributable lung cancer burden (1990-2021)

Age groups	Regions	DALYs (1/100,000)		
		1990 Number (95% CI)	2021 Number (95% CI)	1990-2021 EAPC (95% CI)
65+ Years				
	China	2948.7 (2429.46, 3502.62)	3384.46 (2600.85, 4293.17)	0.62 (0.4, 0.85)
	Global	2411.09 (2230.89, 2594.84)	1928.82 (1672.92, 2200.58)	-0.81 (-0.89, -0.73)
All ages				
	China	414.7 (337.09, 495.11)	839.39 (1074.84, 649.55)	2.49 (2.37, 2.61)
	Global	362.92 (338.83, 389.56)	351.19 (400.39, 309.26)	-0.1 (-0.13, -0.07)

Note: EAPC: Estimated Annual Percentage Change.

adults aged 65 and above showed an upward trend, in contrast to the overall global decline. This may be related to the higher smoking prevalence in China compared with other economies, underlying the urgent need for more effective prevention and early intervention strategies targeting smoking-related lung cancer in the elderly population. Specifically, the DALY rate among the elderly Chinese was consistently higher than both the global average and that of the overall Chinese population. The DALY rate increased from 2,948.7 per 100,000 in 1990 to 3,384.46 per 100,000 in 2021, with an average annual increase of 0.62% (95% CI: 0.4%-0.85%). In contrast, the global DALY rate among those aged ≥65 years decreased from 2,411.09 per 100,000 in 1990 to 1,928.82 per 100,000 in 2021, with an average annual decrease of 0.81% (95% CI: -0.89%--0.73%) (**Figure 1** and **Table 1**).

Similarly, the mortality rates among elderly Chinese (≥65 years) were also higher than those of the general population and significantly exceeded the global average. The mortality rate increased from 150.12 per 100,000 in 1990 to 186.36 per 100,000, with an average annual increase of 0.93% (95% CI: 0.67%-1.19%). Conversely, the global mortality rate decreased from 124.71 per 100,000 in 1990 to 106.26 per 100,000, with an average annual decline of 0.54% (95% CI: -0.64%--0.44%) (**Figure 2** and **Table 2**).

Burden of smoking-attributable lung cancer among different age groups of the elderly population China (1990-2021)

From 1991 to 2021, the DALY rate attributable to smoking-related lung cancer showed an upward trend across all elderly age groups (65-

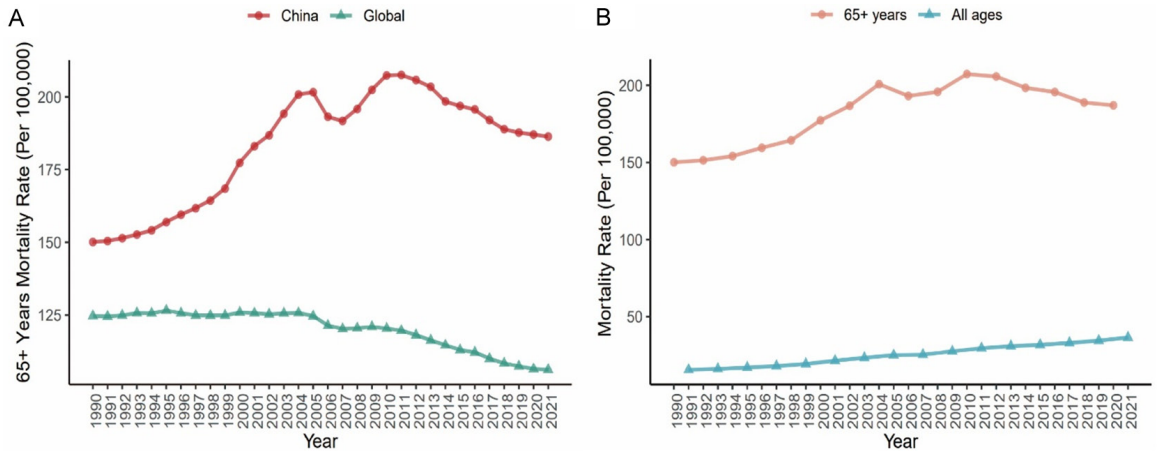

Figure 2. The trends in smoking-attributable lung cancer mortality in China and Globally (1990-2021). A: Comparison of mortality rate in elderly aged ≥65 years between China and Global. B: Comparison of mortality rate between Chinese elderly (≥65 years) and all ages.

Table 2. Trends in smoking-attributable lung cancer mortality (1990-2021)

Age groups	Regions	Mortality (1/100,000)		
		1990 Number (95% CI)	2021 Number (95% CI)	1990-2021 EAPC (95% CI)
65+ Years				
	China	150.12 (123.98, 177.94)	186.36 (143.78, 235.61)	0.93 (0.67, 1.19)
	Global	124.71 (114.91, 134.73)	106.26 (91.51, 121.47)	-0.54 (-0.64, -0.44)
All ages				
	China	15.4 (12.62, 18.21)	36.46 (28.52, 46.51)	3.01 (2.89, 3.14)
	Global	13.84 (12.87, 14.85)	15.15 (13.36, 17.22)	0.3 (0.27, 0.32)

Note: EAPC: Estimated Annual Percentage Change.

69, 70-74, 75-79, 80-84, and ≥85), with increases of 0.23%, 14.96%, 35.50%, 52.52%, and 38.64% respectively. In 1990, the DALY rate initially rose with age and then declined, peaking at 3,282.02 per 100,000 in the 70-74-year group. By 2021, this age-related pattern persisted, but the peak had shifted to the 75-79-year group, reaching 3,852.16 per 100,000. Moreover, the DALY rate in men remained significantly higher than in women, with a male-to-female ratio of approximately 5-9:1 (**Table 3**).

In terms of mortality, smoking-attributable lung cancer deaths also increased across all elderly age groups during the same period. Mortality rates rose by 0.09%, 14.70%, 35.67%, 53.33%, and 40.22% in the 65-69, 70-74, 75-79, 80-84, and ≥85 year groups, respectively. During 1990 and 2021, mortality increased progressively with age, reaching its peak in those aged ≥85 years and above years group. In 1990, the mortality rate for the ≥85-year group increased from 230.05 per 100,000 in 1990 to and 322.58 per 100,000 in 2021. However, the rate of increase in female mortality exceeded that of males in the 65-69 and 75-79-year groups, whereas the opposite pattern was observed in the 70-74, 80-84, and ≥85-year groups (**Table 4**).

Projected disease burden of smoking-attributable lung cancer among elderly Chinese adults aged ≥65 years (2021-2050)

The BAPC model projected that from 2021 to 2050, the number of DALYs attributable to smoking-related lung cancer in China will continue to increase annually, while the DALY rates will show a gradual declining trend. In 2021, DALYs among elderly Chinese men and women aged ≥65 years were 5.66 million and 0.98 mil-

Table 3. Trends in smoking-attributable lung cancer burden stratified by age (1990-2021)

Age groups (Years)	DALYs (10,000 person years)			The rate of DALYs (1/100,000)		
	Total	Female	Male	Total	Female	Male
65-69						
1990	80.85 (66.03, 97.61)	10.09 (7.05, 13.52)	70.75 (55.65, 86.12)	2963.38 (2420.39, 3577.93)	727.49 (508.17, 974.79)	5276.73 (4150.26, 6422.38)
2000	112.12 (99.23, 126.16)	14.89 (11.48, 18.49)	97.23 (85.08, 110.08)	3181.04 (2815.15, 3579.32)	853.94 (658.36, 1059.97)	5460.55 (4778.03, 6182.1)
2010	136.99 (120.2, 155.23)	16.55 (13.2, 20.6)	120.45 (104.4, 137.54)	3314.34 (2908.17, 3755.68)	808.13 (644.71, 1005.99)	5774.13 (5004.67, 6593.73)
2021	227.82 (173.12, 291.6)	30.21 (18.36, 46.6)	197.61 (145.19, 262.51)	2970.11 (2256.96, 3801.61)	775.41 (471.24, 1195.99)	5235.96 (3847.12, 6955.78)
Rate of change between 1990 and 2021 (%)	181.79 (0.93, 2.92)	199.35 (0.68, 4.3)	179.29 (0.82, 2.97)	0.23 (-0.31, 0.4)	6.59 (-0.4, 0.89)	-0.77 (-0.35, 0.41)
70-74						
1990	61.76 (51.11, 72.35)	10.04 (7.37, 13.1)	51.72 (41.61, 61.94)	3282.02 (2716.19, 3844.55)	994.62 (730.6, 1298.12)	5927.79 (4768.55, 7099.04)
2000	97.84 (87.13, 109.35)	15.64 (12.25, 19.2)	82.2 (72.53, 93.04)	3790.81 (3376.15, 4236.85)	1179.5 (924.05, 1448.17)	6549.17 (5778.97, 7413.16)
2010	134.94 (119.54, 151.48)	18.45 (14.95, 22.56)	116.49 (102.15, 131.8)	4060.4 (3597.11, 4558.24)	1104.97 (895.5, 1351.31)	7044.45 (6177.26, 7970.7)
2021	201.09 (153.14, 255.52)	27.6 (17.43, 39.93)	173.49 (128.95, 226.55)	3772.97 (2873.37, 4794.31)	1005.79 (635.35, 1455.21)	6709.61 (4987.03, 8761.73)
Rate of change between 1990 and 2021 (%)	225.59 (1.27, 3.39)	174.94 (0.66, 3.35)	235.42 (1.24, 3.78)	14.96 (-0.2, 0.55)	1.12 (-0.39, 0.6)	13.19 (-0.24, 0.61)
75-79						
1990	32.35 (26.86,37.83)	5.15 (3.51, 7.26)	27.2 (22.12, 32.39)	2842.89 (2359.76, 3324.18)	794.88 (541.63, 1120.34)	5554.44 (4517.88, 6613.72)
2000	56.6 (49.91, 63.34)	9.73 (7.53, 12.13)	46.88 (41.58, 52.91)	3505.23 (3090.48, 3922.28)	1096 (849, 1367.27)	6444.28 (5716.18, 7273.09)
2010	101.97 (90.1, 114.21)	16.14 (12.65, 20.1)	85.83 (74.69, 96.91)	4252.99 (3757.98, 4763.47)	1275.25 (999.74, 1588.15)	7583.32 (6599.53, 8563.12)
2021	127.58 (99.76, 162.84)	19.43 (12.44, 29.62)	108.15 (80.92, 139.95)	3852.16 (3012.2, 4916.93)	1109.23 (710, 1691.15)	6931.58 (5186.25, 8969.55)
Rate of change between 1990 and 2021 (%)	294.32 (1.78, 4.18)	277.01 (1.14, 5.51)	297.6 (1.67, 4.63)	35.50 (-0.04, 0.78)	39.55 (-0.21,1.41)	24.79 (-0.16, 0.77)
80-84						
1990	11.54 (9.61, 13.72)	2.74 (1.98, 3.69)	8.8 (7.14, 10.77)	2179.16 (1813.94, 2590.85)	841.3 (607.29, 1133.09)	4315.49 (3501.87, 5281.15)
2000	22.35 (19.03, 25.46)	5.04 (3.94, 6.16)	17.31 (14.86, 19.7)	2750.92 (2342.3, 3134.22)	1041.24 (812.8, 1271.84)	5273.67 (4527.54, 6002.57)
2010	46.53 (40.67, 52.37)	8.1 (6.15, 10.28)	38.43 (33.62, 43.31)	3691.9 (3227.3, 4155.51)	1113.25 (845.59, 1413.77)	7210.28 (6308.09, 8125.4)
2021	65.78 (51.67, 81.66)	11.73 (6.95, 17.29)	54.05 (40.42, 69.05)	3323.67 (2610.74, 4125.97)	1055.07 (625.31, 1555.62)	6230.86 (4659.44, 7959.92)
Rate of change between 1990 and 2021 (%)	469.87 (3.16, 6.44)	328.01 (1.47, 5.89)	514.03 (3.16, 7.3)	52.52 (0.11, 0.99)	25.41 (-0.28, 1.02)	44.38 (-0.02, 0.95)
85 and more						
1990	4.61 (3.86, 5.46)	1.27 (0.91, 1.7)	3.34 (2.79, 3.99)	2264.43 (1896.5, 2682)	910.2 (648.86, 1216.78)	5228.87 (4375.26, 6255.95)
2000	10.75 (9.29, 12.04)	2.74 (2.07,3.41)	8.01 (7.09, 8.84)	2943.98 (2544.2, 3297.32)	1107.61 (837.01, 1379.29)	6782.59 (5998.6, 7482.95)
2010	20.48 (17.62, 23.14)	4.15 (3.05, 5.36)	16.33 (14.36, 18.2)	3257.54 (2802.64, 3680.78)	976.36 (717.36, 1259.88)	8025.29 (7058.03, 8943.27)
2021	41.12 (32.71, 49.59)	8.56 (5.03, 12.53)	32.56 (24.76, 39.72)	3139.39 (2497.3, 3786.6)	985.53 (579.23, 1442.47)	7381.06 (5613.75, 9005.96)
Rate of change between 1990 and 2021 (%)	792.62 (5.75, 10.41)	573.57 (2.88, 9.75)	876.09 (5.67, 11.72)	38.64 (0.05, 0.77)	8.28 (-0.38, 0.73)	41.16 (-0.04, 0.84)

Table 4. Trends in smoking-attributable lung cancer mortality stratified by age (1990-2021)

Ages groups (Years)	Number of deaths (10,000)			The rate of death (1/100,000)		
	Total	Female	Male	Total	Female	Male
65-69						
1990	3.3 (2.7, 3.98)	0.41 (0.29, 0.55)	2.89 (2.27, 3.52)	120.91 (98.84, 146)	29.72 (20.77, 39.84)	215.26 (169.27, 262.27)
2000	4.58 (4.05, 5.15)	0.61 (0.47, 0.75)	3.97 (3.47, 4.49)	129.9 (114.83, 146.16)	34.89 (26.91, 43.26)	222.96 (195.01, 252.34)
2010	5.59 (4.9, 6.33)	0.68 (0.54, 0.84)	4.91 (4.26, 5.61)	135.15 (118.48, 153.17)	32.99 (26.37, 41.04)	235.43 (204.08, 268.8)
2021	9.28 (7.06, 11.9)	1.23 (0.75, 1.9)	8.05 (5.92, 10.7)	121.01 (92.06, 155.09)	31.63 (19.2, 48.82)	213.29 (156.84, 283.61)
Rate of change between 1990 and 2021 (%)	181.4 (0.93, 2.92)	198.92 (0.68, 4.3)	178.9 (0.82, 2.97)	0.09 (-0.31, 0.39)	6.43 (-0.4, 0.89)	-0.91 (-0.35, 0.41)
70-74						
1990	3.06 (2.53, 3.58)	0.5 (0.37, 0.65)	2.56 (2.06, 3.07)	162.56 (134.65, 190)	49.35 (36.31, 64.37)	293.52 (236.48, 351.42)
2000	4.85 (4.31, 5.42)	0.78 (0.61, 0.95)	4.07 (3.59, 4.61)	187.74 (166.91, 209.84)	58.49 (45.81, 71.89)	324.27 (285.96, 367.02)
2010	6.7 (5.93, 7.53)	0.92 (0.74, 1.12)	5.78 (5.06, 6.54)	201.64 (178.32, 226.49)	54.93 (44.54, 67.15)	349.78 (306.23, 395.43)
2021	9.94 (7.58, 12.65)	1.36 (0.86, 1.97)	8.58 (6.37, 11.21)	186.47 (142.17, 237.4)	49.67 (31.43, 71.94)	331.64 (246.53, 433.58)
Rate of change between 1990 and 2021 (%)	224.87 (1.27, 3.38)	173.67 (0.66, 3.33)	234.83 (1.24, 3.77)	14.70 (-0.2, 0.55)	0.65 (-0.39, 0.59)	12.99 (-0.24, 0.61)
75-79						
1990	2 (1.66, 2.34)	0.32 (0.22, 0.45)	1.68 (1.36, 2)	175.33 (145.54, 205.28)	49.21 (33.52, 69.25)	342.32 (278.34, 407.69)
2000	3.49 (3.08, 3.91)	0.6 (0.47, 0.75)	2.89 (2.56, 3.26)	216.29 (190.6, 241.93)	67.89 (52.52, 84.66)	397.32 (352.15, 448.54)
2010	6.3 (5.57, 7.07)	1 (0.79, 1.25)	5.3 (4.61, 5.99)	262.95 (232.35, 294.69)	79.11 (62.07, 98.51)	468.57 (407.54, 529.58)
2021	7.88 (6.15, 10.07)	1.2 (0.77, 1.83)	6.67 (4.99, 8.65)	237.88 (185.79, 303.99)	68.73 (44, 104.74)	427.77 (319.86, 554.48)
Rate of change between 1990 and 2021 (%)	294.82 (1.79, 4.19)	277.35 (1.14, 5.52)	298.14 (1.68, 4.64)	35.67 (-0.04, 0.78)	39.67 (-0.21, 1.41)	24.96 (-0.16, 0.77)
80-84						
1990	0.91 (0.76, 1.08)	0.22 (0.16, 0.29)	0.69 (0.56, 0.85)	171.5 (142.98, 203.6)	66.43 (48, 89.48)	339.26 (275.51, 414.92)
2000	1.76 (1.5, 2.01)	0.4 (0.31, 0.49)	1.36 (1.17, 1.55)	216.9 (184.78, 247.24)	82.29 (64.3, 100.55)	415.53 (356.83, 472.65)
2010	3.66 (3.2, 4.12)	0.64 (0.49, 0.81)	3.03 (2.65, 3.4)	290.79 (253.8, 326.68)	87.94 (66.75, 111.62)	567.56 (496.67, 638.78)
2021	5.2 (4.09, 6.44)	0.93 (0.55, 1.37)	4.27 (3.19, 5.45)	262.95 (206.69, 325.39)	83.63 (49.59, 123.37)	492.76 (368.29, 628.33)
Rate of change between 1990 and 2021 (%)	472.89 (3.18, 6.48)	329.62 (1.48, 5.92)	517.69 (3.19, 7.36)	53.33 (0.12, 1)	25.88 (-0.27, 1.03)	45.25 (-0.02, 0.96)
85 and above						
1990	0.47 (0.39, 0.55)	0.13 (0.09, 0.17)	0.34 (0.28, 0.4)	230.05 (192.95, 272.73)	92.93 (66.43, 123.77)	530.21 (443.67, 633.1)
2000	1.1 (0.95, 1.23)	0.28 (0.21, 0.35)	0.82 (0.72, 0.9)	301.1 (260.42, 336.5)	114.17 (86.34, 142.34)	691.86 (612.23, 764.01)
2010	2.09 (1.8, 2.37)	0.43 (0.31, 0.55)	1.67 (1.46, 1.85)	332.96 (286.99, 376.41)	100.75 (73.92, 129.83)	818.3 (718.23, 911.01)
2021	4.22 (3.35, 5.09)	0.89 (0.52, 1.31)	3.33 (2.54, 4.08)	322.58 (255.74, 388.59)	102.86 (60.33, 150.59)	755.26 (575.46, 924.75)
Rate of change between 1990 and 2021 (%)	802.81 (5.84, 10.54)	588.61 (2.96, 9.93)	884.99 (5.74, 11.84)	40.22 (0.06, 0.79)	10.69 (-0.36, 0.76)	42.45 (-0.03, 0.86)

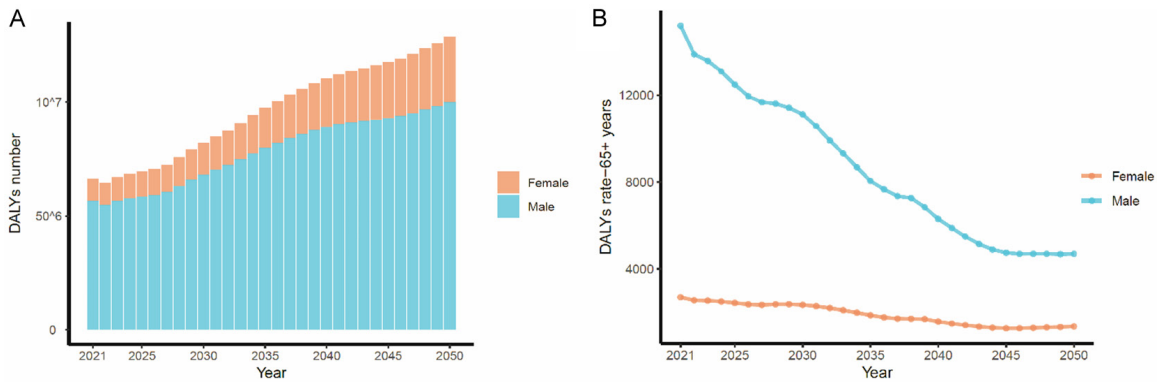

Figure 3. The projected trends of smoking-attributable lung cancer burden among Chinese elderly people from 2021 to 2050. A: The number of DALYs in female and male. B: The rate of DALY rate.

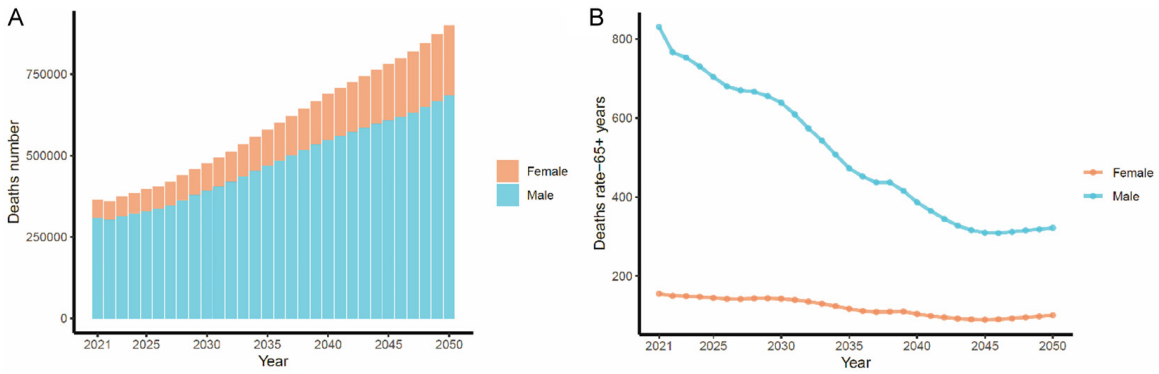

Figure 4. The projected trends of smoking-attributable lung cancer mortality among Chinese elderly people from 2021 to 2050. A: The number of deaths in female and male. B: The rate of deaths.

lion person-years, respectively. By 2050, these values are projected to rise to approximately 14.83 million and 3.53 million person-years, respectively. The growth rate in DALYs among women is projected to exceed that of men. As a proportion of the total national burden, in 2021, DALYs among elderly men and women accounted for 53.95% and 67.09%, respectively. By 2050, these proportions are predicted to increase to 67.39% and 81.15%. Notably, the increase in women's share is greater than that observed in men (**Figure 3**).

In terms of mortality, the projected number of smoking-attributable lung cancer deaths among elderly Chinese adults will also rise steadily between 2021 and 2050. The total number of deaths is expected to increase from 365,400 in 2021 to 1,067,200 in 2050. Among these, male deaths are projected to grow from 309,100 in 2021 to approximately 833,000 in 2050, while female deaths will increase from 56,200 to 234,200, with the relative growth rate for females being slightly higher than that for males. However, the proportion of deaths among those aged ≥65 years in the total number of smoking-attributable deaths across all age groups is expected to decline over time. Among men, this proportion will decrease from 82.28% in 2021 to 68.96% in 2025, while among women, it will decline from 91.24% to 79.71% (**Figure 4**).

Discussion

Previous studies showed that the disease burden of lung cancer attributable to smoking in China had been increasing, with older populations generally bearing a higher disease burden [11, 12]. Based on the latest GBD database, this study retrospectively analyzed the trends of smoking-attributable lung cancer burden among Chinese adults aged ≥65 years from 1990 to 2021 and projected future patterns

from 2021 to 2050 using the BAPC model. Our findings indicate that between 1990 and 2021, the smoking-attributable lung cancer burden to among the elderly in China significantly increased. The DALY rate rose from 2,948.7 per 100,000 in 1990 to 3,384.46 per 100,000 in 2021, with an annual increase of 0.62% (95% CI: 0.4%-0.85%). In contrast, the global DALY rate for the same age group decreased from 2,411.09 per 100,000 in 1990 to 1,928.82 per 100,000 in 2021, with an annual decrease of 0.81% (95% CI: -0.89%--0.73%). This discrepancy may be attributed to the persistently higher smoking prevalence and relatively limited early screening and diagnosis rates for lung cancer among elderly population in China compared with other economies.

Similarly, smoking-related lung cancer mortality among the Chinese elderly remained higher than the global average. From 1990 to 2021, the mortality rate in China increased from 150.12 per 100,000 in 1990 to 186.36 per 100,000, with an annual growth rate of 0.93% (95% CI: 0.67%-1.19%). Globally, the mortality rate decreased from 124.71 per 100,000 in 1990 to 106.26 per 100,000, with an annual decrease of 0.54% (95% CI: -0.64%--0.44%). This opposite trend may reflect a combination of factors: the overall rise in smoking prevalence accompanying rapid urbanization and industrialization, insufficient cancer prevention awareness, inadequate healthcare resources and treatment access, and China's rapidly aging population, which represents a key driver of disease burden [13, 14]. However, it is noteworthy that both DALY rate and mortality rate among China's elderly population peaked around 2010 and had since gradually declined, aligning with global trends in disease burden after 2010. This shift may be attributed to strengthened tobacco control policies, broader health education campaigns, improved living standards, and expanded implementation of early lung cancer screening programs. However, it is important to note that China's disease burden remains significantly higher than the global average, underscoring the need for sustained and targeted tobacco control and prevention strategies.

The disease burden of smoking-attributable lung cancer among elderly Chinese adults aged ≥65 years showed a consistent upward trend across all age groups between 1990 and 2021. By 2021, the DALY rates in the 65-69, 70-74, 75-79, 80-84, and ≥85-year groups had increased by 0.23%, 14.96%, 35.50%, 52.52%, and 38.64%, respectively, compared with 1990. The most rapid growth occurred among those aged ≥75 years, who also exhibited the highest incidence and mortality rates, underscoring the need for targeted lung health management and early detection in this age group. Across time, the distribution of DALY rates among age groups showed a pattern of first increasing and then decreasing with age. From 1990 to 2021, the highest DALY rates was observed in the 70-74-year group. Similarly, smoking-attributable lung cancer mortality among the elderly population aged ≥65 years in China also rose across all age groups. By 2021, mortality in the 65-69, 70-74, 75-79, 80-84, and ≥85-year groups had increased by 0.09%, 14.70%, 35.67%, 53.33%, and 40.22%, respectively, compared with 1990. The disease burden increase was particularly pronounced among individuals aged ≥75 years, with the ≥85-year group exhibiting the highest overall mortality.

In terms of gender differences, the conclusions from this study were consistent with previous studies [15, 16], indicating that both the severity and growth rate of the disease burden were generally higher in males than in females. This discrepancy is primarily attributed to male's higher exposure to smoking and other related risk factors [17, 18], as well as their significantly higher lung cancer incidence rates [19, 20]. Nevertheless, recent studies have revealed that since 2017, secondhand smoke exposure and environmental pollution have contributed to increasing lung cancer incidence and mortality among non-smokers, particularly women and the elderly [21, 22]. Therefore, lung cancer prevention efforts should not only focus on reducing direct smoking-related risks but also address the secondary effects of smoking. Strict smoking bans should continue to be enforced, while early prevention, health education, and screening initiatives should be strengthened, especially among older adults and women.

The findings of this study further indicate that as Chinese population continues to age, coupled with ongoing lifestyle changes and persis-

tent environmental pollution, the disease burden of lung cancer attributable to smoking among individuals aged ≥65 years is projected to rise steadily. Our projections indicate that by 2050, the DALYs for men and women will increase from 5.6586 million and 0.9753 million person-years in 2021 to approximately 14.8316 million and 3.5285 million person-years, respectively. Correspondingly, the number of deaths among men and women is expected to rise from 309,100 and 56,200 in 2021 to approximately 833,000 and 234,200, respectively. These finding indicate that the rate of increase in smoking-attributable lung cancer burden among elderly women will surpass that among men in the future. When stratified by sex, the proportion of DALYs and mortality among adults aged ≥65 years relative to the total population of each gender is also projected to increase over time. Although women account for a higher proportion of the total population, the growth rate of the male burden remains higher. These trends highlight the urgent need to develop gender-specific public health intervention, particularly, strengthening smoking-cessation programs for high-risk populations (such as elderly women) and initiating earlier annual screening for smokers [23, 24]. In addition, public health authorities should not only strengthen comprehensive tobacco-control measures but also promote the development of innovative medications to alleviate the growing disease burden among the elderly population.

However, this study has several limitations. First, lung cancer comprises two major histological subtypes - non-small cell carcinoma and small cell carcinoma - which differ substantially in their risk factors and incidence trends. Second, the GBD database does not provide separate data for these subtypes, nor does it include detailed information on smoking duration and frequency among the elderly population in China. This limitation restricts a more comprehensive assessment of the dose-response relationship between smoking exposure and lung cancer risk. Third, the results of this study were derived from the GBD 2021, which integrates data from multiple sources, such as unpublished and published data. Some smoking-related data were indirectly estimated, introducing potential biases. Therefore, further studies should focus on subtype-specific analyses of smoking-attributable lung cancer and improving the precision of smoking exposure data to enhance the robustness of future estimations.

In conclusion, the smoking-attributable lung cancer burden among China's elderly population had increased from 1990 to 2021, and projections suggest that both DALYs and deaths will continue to rise in the coming decades. Stricter tobacco control policies, gender- and age-targeted health interventions, and enhanced early screening programs are urgently needed to relieve this burden.

Disclosure of conflict of interest

None.

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