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Trends in tobacco smoking and bladder and lung-bronchial cancer rates among non-hispanic white Americans (2000–2016)

Diancarlos Pereira de Andrade[1,2], Camila Moraes Marques[1,2], Dayane Christina Rodrigues de Andrade[3], Luana Lenzi[4], Cláudia Sirlene Oliveira[1,2] and Bonald Cavalcante de Figueiredo[1,2*]

Abstract

Background Cancer incidence may be linked to cumulative exposure to environmental factors, including diet, lifestyle behaviors, licit drug use (such as tobacco), and endogenous processes. Tobacco smoking (TS) is strongly associated with bladder cancer (BC) and lung-bronchial cancer (LBC). This study aimed to analyze TS, BC, and LBC rates; their correlation with sex and age; and the risk of subsequent primary cancers among BC and LBC patients in non-Hispanic white Americans (NHWAs) from 13 U.S. states.

Methods The percentage of smokers in 13 U.S. states from 2000 to 2016 was obtained from the Centers for Disease Control and Prevention (CDC) database. LBC and BC cases in NHWAs from 2000 to 2016 were analyzed as single primary cancers or as the first of two or more neoplasms using the United States Surveillance, Epidemiology, and End Results (SEER) database.

Results The percentage of NHWA smokers decreased in all 13 U.S. states evaluated in this study from 2000 to 2016. Over 17 years, the incidence rates of BC were 36.37 and 11.66 cases per 100,000 among men and women, respectively, while those of LBC were 68.21 and 61.53 cases per 100,000, respectively. The highest incidence rates of BC and LBC occurred in individuals over 64 years of age: BC in New York (208.9 per 100,000 men) and Massachusetts (54.33 per 100,000 women), and LBC in Kentucky (503.1 per 100,000 men; 298.5 per 100,000 women). The incidence rates of BC and LBC were correlated in most states, especially in Massachusetts, California, New Jersey, and New York. Among the 657,117 patients with LBC, 4.3% had a second type of cancer, while among the 240,461 patients with BC, 14.3% had a second type.

Conclusion Despite a significant decrease in the number of smokers in the United States between 2000 and 2016, the incidence of BC in men and LBC in women has not followed a similar decline. The odds ratio of a patient diagnosed with primary BC developing a second neoplasm is 3.3 times greater than that of a patient diagnosed with primary LBC.

Keywords Bladder cancer, Lung cancer, Bronchial cancer, Smoking

*Correspondence:
Bonald Cavalcante de Figueiredo
bonaldf@yahoo.com.br; bonald.figueiredo@yprofessor.fpp.edu.br
[1]Instituto de Pesquisa Pelé Pequeno Príncipe, Curitiba 80.250-200, PR, Brazil
[2]Faculdades Pequeno Príncipe, Curitiba 80.230-020, PR, Brazil
[3]Hospital de Clínicas de Porto Alegre, Porto Alegre 90.035-903, RS, Brazil
[4]Departamento de Análises Clínicas, Universidade Federal do Paraná, Curitiba 80210-170, PR, Brazil

Text box 1. Contributions to the literature

• This study provides a comprehensive analysis of bladder and lung-bronchial cancer incidence trends in the USA from 2000 to 2016, highlighting variations by age, sex, and state.

• This study revealed a high incidence of bladder and lung-bronchial cancer in individuals over 64 years old, as well as a significant correlation between the incidence of these cancers in certain U.S. states.

• This study enhances the understanding of demographic disparities in bladder and lung-bronchial cancer incidence, emphasizing the need for targeted public health interventions.

Introduction

Cancer incidence is related to cumulative exposure to environmental factors, such as diet, lifestyle habits, and occupational hazards [1, 2]. The concept of the exposome, which integrates external exposures and their effects on the genome, helps in understanding the impact of factors such as radiation and smoking on the occurrence of cancers, including bladder and lung cancer [3, 4, 5]. Smoking can cause cancer in almost any part of the body, including the bladder, esophagus, liver, lungs, bronchi, and trachea. Studies have shown that cigarette smoke contains over 7,000 chemicals, at least 69 of which can cause cancer [6].

According to the International Agency for Research on Cancer, bladder cancer (BC) is the 10th most common neoplasm worldwide, the 6th most common in men, and the 17th most common in women. The incidence of BC in men is four times higher than in women, with a mortality rate of 3.2 per 100,000 [7]. The highest incidence is found in southern Europe, particularly in Greece, as well as in Western European countries (the Netherlands and Belgium), North America, and Lebanon (which has the highest rate in women) [7]. In the United States (USA), BC is the 4th most common neoplasm in men. It ranks 8th in cancer mortality, with an estimated 83,190 new cases and 16,840 deaths in 2024, and a mean age at diagnosis of 73 years [8]. From 2000 to 2004, the 5-year survival rate was 78% [9]. The main risk factors associated with BC included male sex; age over 45 years, smoking, occupational exposure to toxic agents such as aromatic amines, aromatic hydrocarbons, arsenic, and radiation, genetic mutations in certain oncogenes and tumor suppressor genes, and the use of certain medications such as phenacetin, cyclophosphamide, and chlornaphazine [10, 11]. According to Strope and Montie [12], smoking is the greatest risk factor for BC, having been reported in up to 50% of cases.

Lung-bronchial cancer (LBC) is more prevalent among men worldwide, and its incidence and mortality are linked to smoking. In developed countries such as the USA and the United Kingdom, the incidence of LBC has been decreasing since the 1990s, following anti-smoking campaigns [13, 14]. LBC usually starts in the cell lining of the bronchi and parts of the lung, such as the bronchioles and alveoli [15]. The risk factors for LBC include lifestyle, environmental and occupational exposures, smoking, pollution, geographic location, sex, race, and genetics.

This study aimed to analyze smoking, BC, and LBC rates, as well as the correlation of these factors with sex and age in non-Hispanic white Americans (NHWAs) from 13 U.S. states. This study also aimed to examine the risk of subsequent primary cancers among survivors of BC and LBC. Understanding the risk factors and disease characteristics may contribute to preventive measures and social policies aimed at reducing morbimortality, preventing disease progression, and avoiding secondary malignancies.

Methods

This quantitative, retrospective study used data from the Surveillance, Epidemiology, and End Results (SEER) and the Centers for Disease Control and Prevention (CDC) databases.

Cancer data were obtained from the SEER 21 Regs Limited-Field Research Data + Hurricane Katrina-impacted Louisiana cases, November 2018 Sub, covering the years 2000–2016, from 13 U.S. states: California (CA), Connecticut (CT), Georgia (GA), Hawaii (HI), Idaho (ID), Iowa (IA), Kentucky (KY), Louisiana (LA), Massachusetts (MA), New Jersey (NJ), New Mexico (NM), New York (NY), and Utah (UT). BC (ICD-10 codes: C67.0 to C67.9) data were filtered from cases in each state by selecting those classified as primary according to international rules, including single cases and the first record of multiple cancer cases. LBC (ICD-10 codes: C34.0 to C34.9) records were filtered to include those registered as single cases or as the first of two or more cancer cases.

The variables used in the study included sex, race, ethnicity, age at diagnosis (categorized into three age groups), and the U.S. state and year of occurrence. To calculate the incidence of BC and LBC in each U.S. state, the USA census data from the SEER (Populations – Total USA 1970–2017, Division of Cancer Control and Population Sciences, Surveillance Research Program, released December 2018) were used. Annual estimates of the resident population were selected based on sex, year, origin (ethnicity), and state.

Statistical analysis

All descriptive and inferential analyses were conducted using the R Cran programming language (version 4.0.2, released on 2020-06-22) [16]. This tool generates reports, tables, and graphs using packages and functions appropriate for the applied tests. For the descriptive analyses, measures of central tendency, dispersion, and frequency were calculated and presented in graphs and tables. The percentage of the population that self-identified as former smokers and maintained their smoking status was calculated, considering state, race, and ethnicity. For comparisons between categories, the chi-square test and Mantel−Haenszel test [17, 18] were applied to assess associations (BC vs. age, LBC vs. age, BC vs. sex, LBC vs. sex). Pearson's correlation was used to investigate potential linear relationships between the incidence of BC and LBC [19]. To examine the relationships among the incidences of these cancers, a local polynomial regression model (LOESS - locally estimated scatterplot smoothing) was employed, allowing for a more detailed adjustment of the trends observed in the data.

Results

Smoking rates among Americans of all races

Among individuals aged 45–64 years, the percentage of smokers across all ethnicities decreased from 28.22 to 11.27%, with an average of 18.51%. However, among individuals aged over 64 years, the percentage of smokers decreased from 12.48 to 4.35%, with an average of 8.40% (Supplementary Fig. 1).

Smoking rates among NHWAs

The percentage of NHWA smokers across all ages (male and female) decreased in the 13 U.S. states evaluated in this study from 2000 to 2016 as follows: 17.1% (2000) vs. 12.1% (2016) in CA; 20.1% vs. 12.6% in CT; 25.6% vs. 19.0% in GA; 20.6% vs. 12.7% in HI; 21.6% vs. 14.8% in ID; 22.8% vs.16.4% in IA; 30.9% vs. 24.3% in KY; 26.2% vs. 22.6% in LA; 20.1% vs. 14.2% in MA; 21.8% vs. 15.2% in NJ; 25.8% vs. 15.4% in NM; 22.6% vs. 15.7% in NY; and 12.6% vs.8.1% in UT (Fig. 1).

BC and LBC among NHWAs

Between 2000 and 2016, 5,021,982 cancer cases were registered among NHWAs as either a single primary cancer or the first of two or more primary cancers. A total of 240,461 BC cases (75.20% in males; 24.80% in females) were analyzed across 13 U.S. states. The ages at diagnosis for BC were 0–44 years, 45–64 years, and over 64 years in 2.4%, 28%, and 69.6% of patients, respectively. There were 657,117 LBC (48.30% in female; 51.70% in male), with ages at diagnosis of 0–44 years, 45–64 years, and over 64 years in 1.7%, 31.1%, and 67.2% of cases, respectively (Table 1).

The overall average BC incidence rates (per 100,000, male and female combined) were as follows: CA, 23.02; CT, 28.26; GA, 18.42; HI, 29.44; ID, 19.80; IA, 21.35; KY, 20.20; LA, 19.51; MA, 25.79; NJ, 28.14; NM, 27.10; NY, 29.02; and UT, 10.85 (Table 1). The incidence of BC (per 100,000) in NHWAs by state and sex is shown in Fig. 2 and Supplementary Table 1. A linear relationship was observed throughout the study period (2000–2016). A downward trend in the incidence of BC was observed over the study period among males in MA and NJ. In contrast, there was an increasing trend among males in CA, CT, GA, HI, ID, IA, KY, LA, NM, NY, and UT. With respect to women, the incidence of BC decreased in HI,

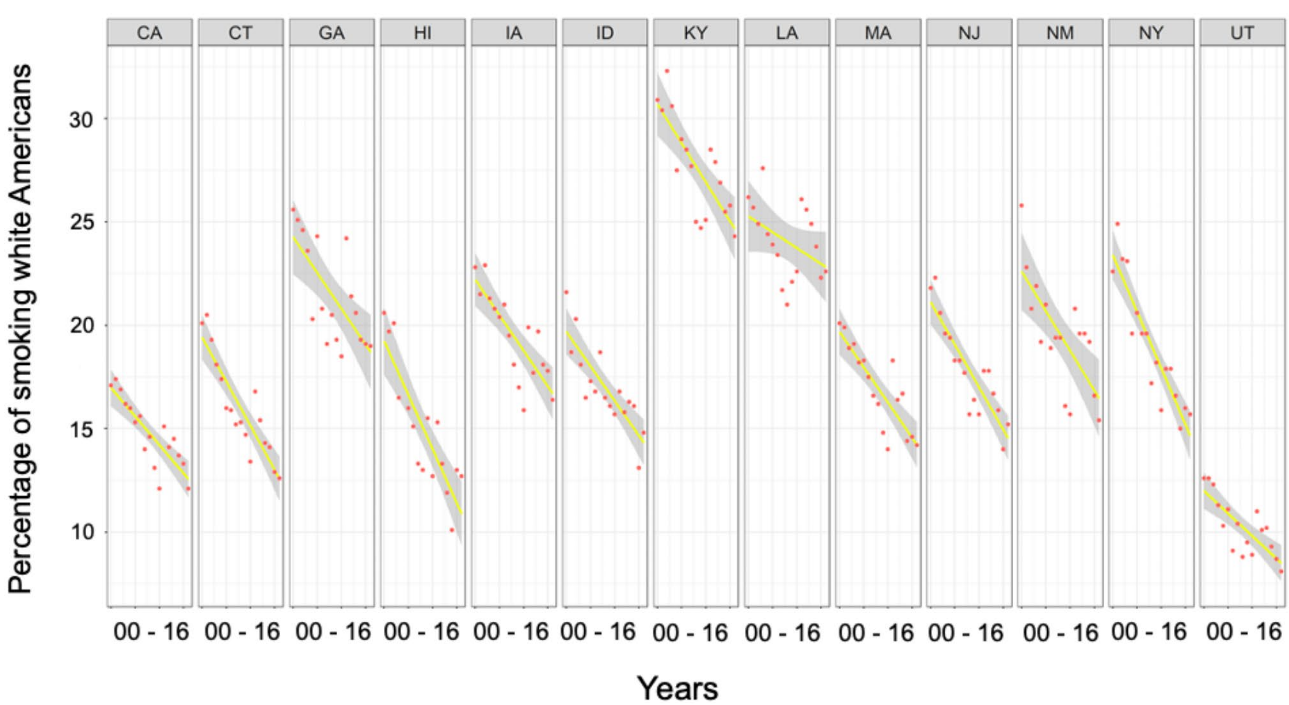

Fig. 1 Percentage of non-Hispanic white Americans (NHWAs) who smoked across all age groups. Each panel represents the incidence during the period (2000–2016) by U.S. state (95% confidence interval)

Table 1 Bladder cancer (BC) and lung-bronchial cancer (LBC) percentage and incidence in in non-Hispanic white Americans (NHWAs) from 2000 to 2016

Variables	BC *N* (%)	BC Incidence[a] (per 100,000)	LBC *N* (%)	LBC Incidence[a] (per 100,000)
Sex				
Female	59,532 (24.8)	11.66	317,504 (48.3)	61.53
Male	180,929 (75.2)	36.37	339,613 (51.7)	68.21
Age group				
0 to 44 years	5,737 (2.4)	1.03	11,347 (1.7)	2.01
45 to 64 years	67,440 (28.0)	23.69	204,046 (31.1)	71.68
> 64 years	167,284 (69.6)	102.10	441,724 (67.2)	269.60
American State				
California	61,705 (25.7)	23.02	156,816 (23.9)	58.51
Connecticut	12,465 (5.2)	28.26	29,563 (4.5)	67.02
Georgia	16,985 (7.1)	18.42	62,064 (9.4)	67.30
Hawaii	1,126 (0.5)	29.44	2,585 (0.4)	60.27
Idaho	9,716 (4.0)	19.80	29,399 (4.5)	46.36
Iowa	4,039 (1.7)	21.35	10,172 (1.5)	63.57
Kentucky	12,864 (5.3)	20.20	58,153 (8.8)	91.33
Louisiana	9,070 (3.8)	19.52	32,544 (5.0)	68.88
Massachusetts	22,528 (9.4)	25.79	59,331 (9.0)	67.93
New Jersey	25,652 (10.7)	28.14	62,107 (9.5)	68.12
New Mexico	3,260 (1.4)	27.10	9,013 (1.4)	65.24
Ney York	57,106 (23.7)	29.02	138,450 (21.1)	70.36
Utah	3,945 (1.6)	10.85	6,920 (1.1)	18.68

Number (*N*) and percentage (%) of cancer cases. [a]one primary only and first of two or more primaries

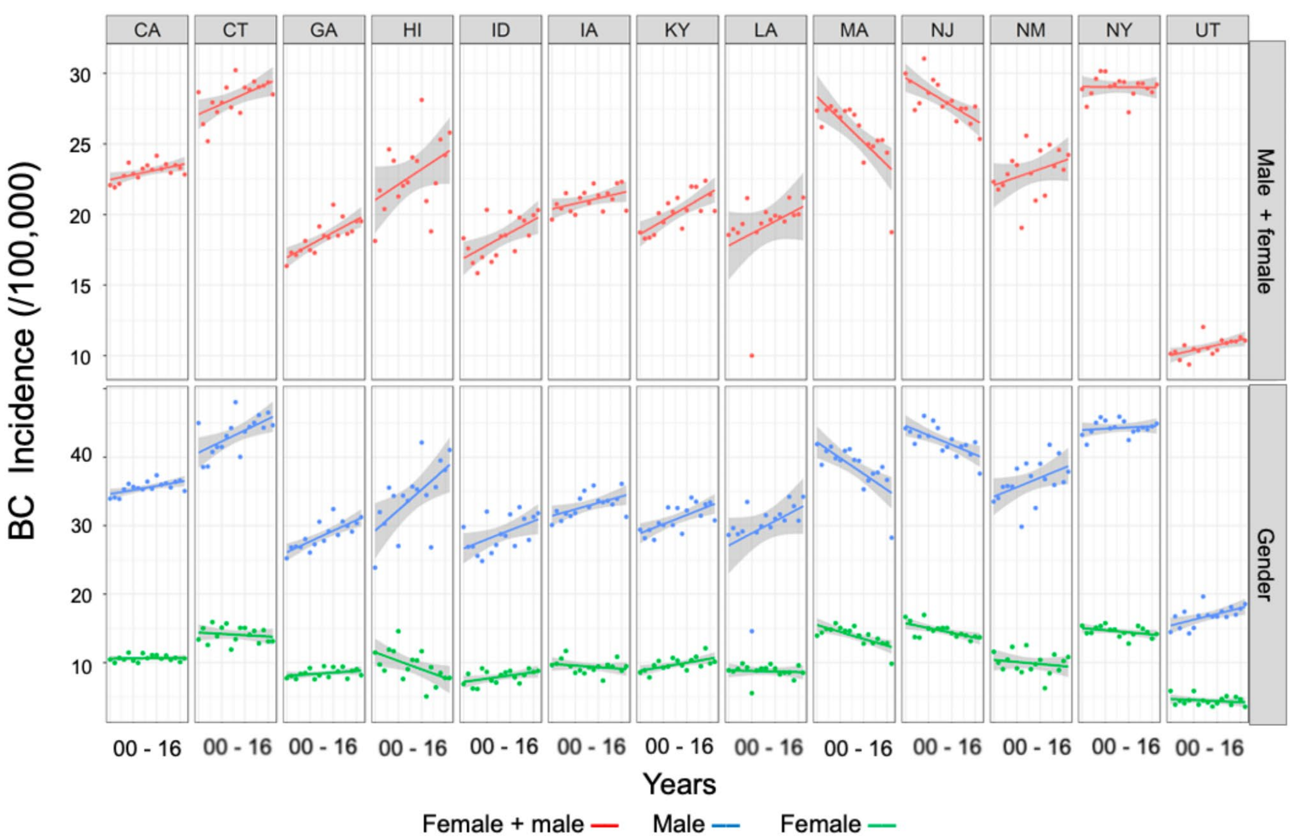

Fig. 2 Bladder cancer (BC) incidence. Each panel represents the incidence during the period (2000–2016) by U.S. state (95% confidence interval). The bottom panel shows the overall incidence (males + females), while top panel represents the incidence stratified by sex

MA, and NJ, but remained almost constant over the years in the other states evaluated in this study. The incidence of BC was significantly greater among men than women in all American states evaluated in this study ($p < 0.05$).

The overall average LBC incidence (per 100,000, male and female combined) was as follow: CA, 58.51; CT, 67.02; GA, 67.30; HI, 60.27; ID, 46.36; IA, 63.57; KY, 91.33; LA, 68.88; MA, 67.93; NJ, 68.12; NM, 65.24; NY, 70.36; and UT, 18.68 (Table 1). The incidence of LBC (per 100,000) by state over the years, according to sex, is presented in Fig. 3 and Supplementary Table 1. A linear relationship was observed throughout the study period (2000–2016). A downward trend in the incidence of LBC was observed over the study period among males in all 13 U.S. states evaluated. With respect to females, a downward trend was observed in CA, CT, HI, MA, and NJ, while an upward trend was observed in GA, ID, IA, KY, LA, NM, and UT. No statistically significant difference in the incidence of LBC between men and women was observed across the U.S. states evaluated, except in IA and KY.

BC and LBC incidence by age

The overall mean age of patients (male and female) diagnosed with BC was 70.41 ± 12.25 years. For females, the mean age was 71.57 ± 13.0 years, whereas for males, it was 70.03 ± 11.97 years. The LBC overall mean age (male and female) was 69.34 ± 11.36 years. For females, the mean age was 69.92 ± 11.65 years, whereas for males, it was 68.80 ± 11.05 years (Supplementary Table 2).

For CA and CT, females (72.54 and 72.14 years, respectively) and males (70.73 and 70.44 years, respectively) had the highest mean age at BC diagnosis. Conversely, the lowest mean age at diagnosis was observed in males in the GA (68.48 years) and females in the UT (69.13 years). For LBC, CA had the highest mean age at diagnosis (females, 71.32; males, 67.40), whereas KY had the lowest mean age (females, 69.81; males, 66.97) (Supplementary Fig. 2).

The incidences of BC and LBC according to age at diagnosis in the three age groups are shown in Fig. 4 and Supplementary Table 3. The group aged > 64 years presented a decrease in BC and LBC incidence across all the studied American states. The highest incidence of BC in the first age group (0–44 years) was observed in HI, with 2.51 in males and 1.89 in females. In the second age group (45–64 years), the highest incidence was found in NY (45.08 in males and 13.7 in females). In the third age group (> 64 years), the highest incidence was observed in NY (208.90 in males), followed by MA (54.33 in females).

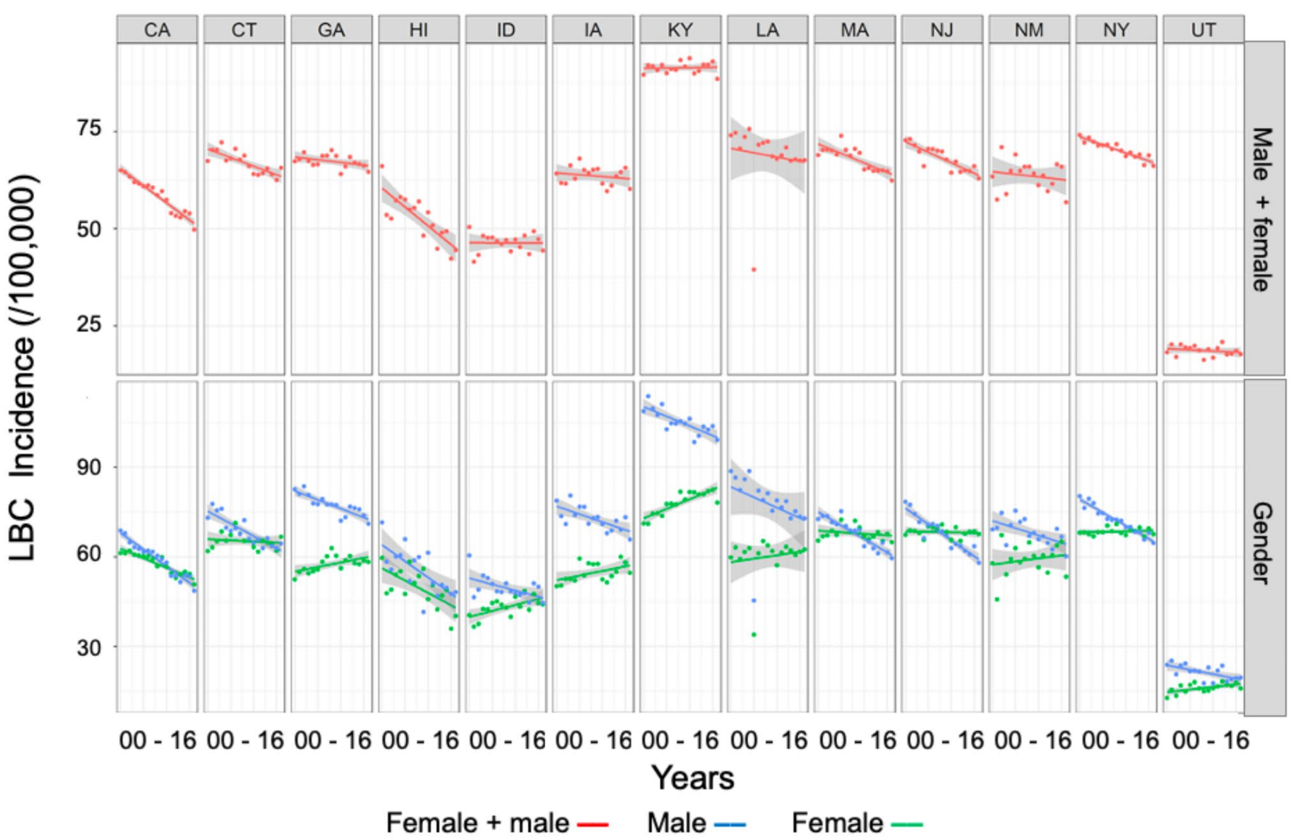

Fig. 3 Lung-bronchial cancer (LBC) incidence. Each panel represents the incidence during the period (2000–2016) by U.S. state (95% confidence interval). The bottom panel shows the overall incidence (males + females), while top panel represents the incidence stratified by sex

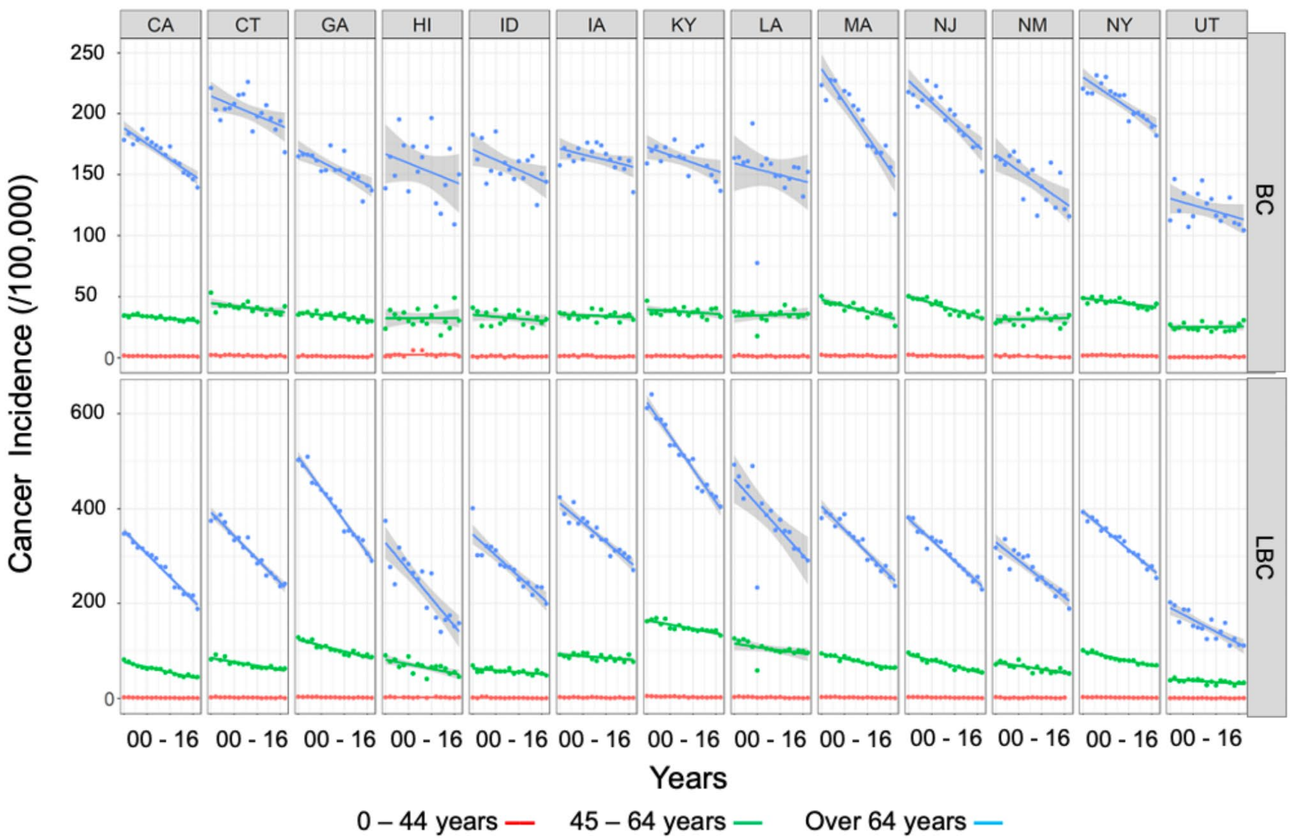

Fig. 4 Incidence of bladder cancer (BC; top panel) and lung-bronchial cancer (LBC; bottom panel) by age group. The incidence by age of diagnosis (per 100,000) was calculated for three age groups: 0–44, 45–64, and over 64 years

For LBC across all age groups, the highest incidence was observed in KY, with the following values: 0–44 years, 3.33 in males and 3.6 in females; 45–64 years, 149.9 in males and 104.0 in females; and > 64 years, 503.1 in males and 298.5 in females.

BC and LBC correlation

The Pearson correlation was calculated between the incidence of BC and LBC in each U.S. state and the population of men over 64 years (Supplementary Table 4). A significant positive correlation was found between BC incidence and LBC incidence in MA (Fig. 5A; $r = 0.94$, $p < 0.001$), CA (Fig. 5B; $r = 0.93$, $p < 0.001$), NY (Fig. 5C; $r = 0.90$, $p < 0.001$), and NJ (Fig. 5D; $r = 0.86$, $p < 0.001$). Moderate positive correlations were found for NM ($r = 0.69$, $p < 0.002$), GA ($r = 0.73$, $p < 0.001$), LA ($r = 0.77$, $p < 0.001$), IA ($r = 0.53$, $p < 0.03$), KY ($r = 0.49$, $p < 0.045$), ID ($r = 0.53$, $p < 0.03$), and CT ($r = 0.55$, $p < 0.02$). No significant correlation was found between BC incidence and LBC incidence in HI and UT ($p > 0.05$).

Secondary neoplasm after BC or LBC

Among the 240,461 patients with BC, 14.30% (34,385) developed a second type of cancer (Table 2), including prostate cancer (695.08 per 10,000), LBC (279.35 per 10,000 in females; 304.71 per 10,000 in males), kidney cancer (36.62 per 10,000 in females; 60.74 per 10,000 in males), and breast cancer (185.29 per 10,000 in females; 3.26 per 10,000 in males). Among the 7,176 LBC patients who died after BC, the majority were male (76.8%), and most were aged over 64 years (75%).

Among the 657,117 patients with LBC, 4.3% (28,256) developed a second type of cancer (Table 2). The second primary neoplasm after LBC was LBC itself (incidence of 130.24 per 10,000 in females and 95.56 per 10,000 in males). The third primary neoplasm was breast cancer (incidence of 75.34 per 10,000 in females; 1.0 per 10,000 in males), and the third and fourth primary cancers after LBC were BC (incidence of 18.68 per 10,000 in females; 48.26 per 10,000 in males) and prostate cancer (incidence of 65.34 per 10,000). Among the 2,232 BC cases after LBC, the highest percentage was found in males (73.4%), followed by those aged over 64 years (77.37%).

The relative risk of developing a second neoplasm is 3.3 times greater in patients diagnosed with primary BC than in those diagnosed with primary LBC (95% CI: [3.27–3.38], $p < 0.0001$).

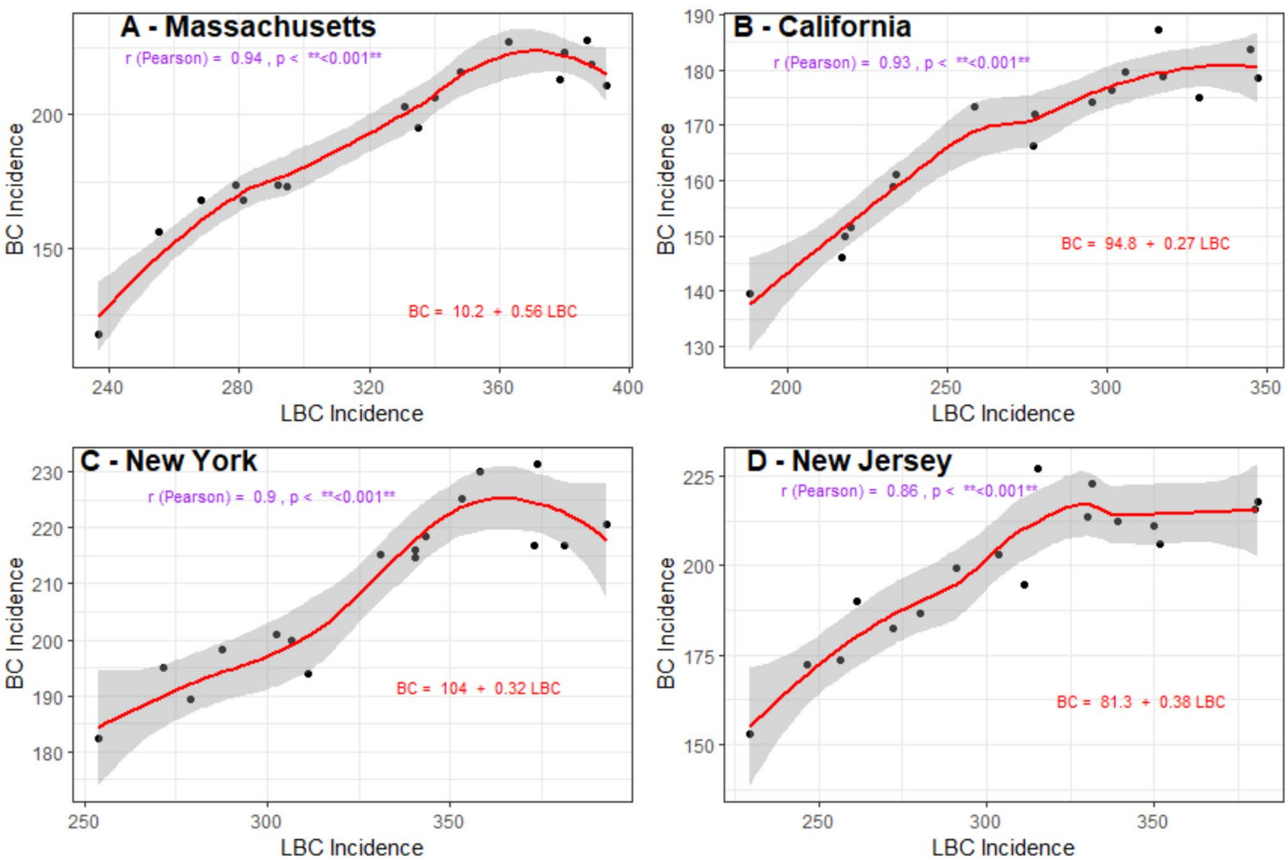

Fig. 5 Locally Estimated Scatterplot Smoothing (LOESS). The red line represents the smoothing of the weighted local scatter plot for the recorded points of bladder cancer (BC) and lung-bronchial cancer (LBC) incidence."

Discussion

When studying the incidence of neoplasms and the regional characteristics that influence cancer emergence, the environment must be considered. Understanding the habits and environment of a population can lead to the creation of impactful population-targeted prevention policies. In this study, we demonstrate that age, sex, and smoking are associated with the development of BC and LBC in 13 U.S. states.

Tobacco use is a common risk factor for both BC and LBC [12, 20, 21, 22]. Smoking has been reported in up to 50% of BC patients and is considered a high-risk factor for BC development. This risk decreases by up to 40% within four years of smoking cessation [10, 12, 23]. Here, we demonstrate that the percentage of smokers in the NHWAs has generally decreased. The incidence curves of BC tended to increase over the study period (2000–2016) in males in the majority of the U.S. states evaluated (CA, CT, GA, HI, ID, IA, KY, LA, NM, NY, and UT). This trend was not observed in females. BC is the 10th most common cancer worldwide, with the highest incidence among males [8, 11, 24, 25]. In some countries, the incidence of BC in females has increased, while in males, it has decreased or remained stable [24]. This study confirmed a male predominance in BC incidence, with rates of 36.37 cases per 100,000 men compared to 11.66 cases per 100,000 women across all U.S. states. Interestingly, when BC incidence curves were categorized by age, a decrease in incidence was observed, particularly in those aged over 64 years. In contrast to the decrease in BC incidence, the percentage of smokers over 64 years old, across all ethnicities, remained nearly the same from 2000 to 2016. Therefore, the decrease in cancer incidence among those aged over 64 years is not solely due to smoking.

Regarding LBC, smoking is strongly associated with the development of this cancer [9, 22]. Interestingly, we observed a decrease in LBC incidence among men during the study period, which parallels the decline in tobacco smoking. In contrast, the incidence in women tended to increase over time. In this context, growing evidence suggests that LBC rates among non-smokers are increasing, particularly among women. Factors such as female hormones (e.g., estrogen) and genetic predispositions may play a role in the development of LBC [26]. Similar to BC, when incidence rates were evaluated by age, a decrease in LBC incidence was observed over the years, particularly in individuals aged over 64 years. It may be a cohort

Table 2 Second primary cancer after bladder cancer (BC) and lung-bronchial cancer (LBC) in non-Hispanic white Americans (NHWAs) from 2000 to 2016

Cancer	Total of FMC *N*(%)*	Incidence with two or more **	First incidence after[(a)]	Second incidence after[(b)]	Third incidence after[(c)]	Fourth incidence after[(d)]
BC						
Both Sex	240,461	1429.63	695.08 in prostate	298.43 in lung	54.78 in kidney	48.32 in breast
Female	59,532(24.8)	941.17	-	279.35	36.62	185.29
Male	180,929(75.2)	1590.35	695.08	304.71	60.74	3.26
LBC						
Both Sex	657,117	433.67	112.32 in lung	36.89 in breast	33.97 in bladder	65.34 in prostate
Female	317,504(48.3)	470.10	130.24	75.34	18.68	-
Male	339,613(51.7)	398.78	95.56	1.0	48.26	65.34

FMC - First Malignant Cancer; N(%)* - number and percentage of cases in the NHWA (one primary only e 1st of two or more primaries); ** Incidence of cases in NHWA (1st of two or more primaries) per 10,000; a – first highest incidence after first cancer (per 10,000); b – second highest incidence after first cancer (per 10,000); c – third highest incidence after first cancer (per 10,000); d – fourth highest incidence after first cancer (per 10,000)

effect, but more studies are needed to confirm this. Corroborating this hypothesis, the rate of LBC in Hungary increased among older individuals from 2011 to 2016 [27].

According to the CDC, the overall life expectancy for the U.S. population is 78.8 years. Between 2000 and 2014, the life expectancy in the NHWA population increased by 1.4 years [28]. In this study, females had the highest mean age at diagnosis: 71.57 years for females vs. 70.03 years for males in BC, and 69.92 years for females *versus* 68.80 years for males in LBC. Age at diagnosis is a key factor in the development of BC and LBC [8, 9]. The average age at diagnosis is 73 years for BC patients and over 70 years for LBC patients across all races [22, 29, 30]. In this study, the mean age at diagnosis for the NHWA population was 70.41 years [SD: 12.25] for BC patients and 69.34 years [SD: 11.36] for LBC patients. Eastern states such as CT, MA, NJ, and NY had higher incidence rates, particularly among those aged over 64 years, while UT, in the Rocky Mountain region, consistently presented the lowest incidence across all age groups. Despite differences in cancer incidence, life expectancy in these states shows minimal variation, ranging from 77.3 years (NJ, males) to 82.9 years (CT, males), according to CDC data [31].

Although BC and LBC differ, they share several common risk factors, including age, sex, and tobacco use, all of which contribute to their incidence. Using Pearson correlation analysis, we examined the relationship between the incidence of BC and LBC across the U.S. states. When all the states were analyzed together, the correlation coefficient was 0.41 ($p < 0.001$). In addition, the Pearson correlation between BC and LBC by state among men over 64 years old is nearly perfect in MA, CA, NY, and NJ. This strong correlation suggests that understanding the incidence of one of these cancers may help estimate the behavior of the other. For example, in MA, an increase of 10 cases per 100,000 in the incidence of LBC among men over 64 years could correspond to an increase of 5.6 cases per 100,000 in the incidence of BC ($BC = 10.2 + 0.56 \times LBC$).

The second approach to finding an association between BC and LBC was to analyze other primary cancers that occurred after the first primary cancer (BC or LBC). Among the 240,461 patients with BC, 14.3% (34,337) had a second neoplasm. On the other hand, 4.3% (28,497) of the 657,117 LBC patients had a second neoplasm. These findings indicate that the odds ratio of having a second neoplasm is 3.3 times greater in patients with a primary BC diagnosis than in those with a primary LBC diagnosis (odds ratio = 3.33 [3.27–3.38], $p < 0.0001$). This finding aligns with a previous study showing that BC survivors had the highest risk of developing a second cancer in the USA between 1992 and 2008 [32].

Conclusions

A general decline in the percentage of smokers within the NHWA population was observed over time; however, this trend was not consistent across all age groups. Notably, the reduction in BC and LBC incidence among individuals aged over 64 years did not directly correlate with smoking prevalence in this group. While the overall incidence of BC has declined, particularly in older age groups, a concerning increase has been observed among younger men. With respect to LBC, a decrease in incidence was observed in men, while an increase was observed in women from 2000 to 2016. This trend highlights the need for targeted prevention strategies to address the specific risk factors contributing to this demographic shift. The findings also revealed a complex interplay between BC and LBC, characterized by shared risk factors and an increased likelihood of developing a second primary cancer among individuals with a history of BC. Understanding these interconnections is essential for designing comprehensive cancer prevention and control programs that support individuals in remission, as well as their family members, by educating them the signs of possible cancer recurrence and ways to prevent it.

Abbreviations

BC	Bladder cancer
CA	California
CDC	Centers for Disease Control and Prevention
CT	Connecticut
GA	Georgia
HI	Hawaii
IA	Iowa
ID	Idaho
KY	Kentucky
LA	Louisiana
LBC	Lung-bronchial cancer
LOESS	Locally Estimated Scatterplot Smoothing
MA	Massachusetts
NJ	New Jersey
NM	New Mexico
NY	New York
SEER	The Surveillance, Epidemiology, and End Results
TS	Tobacco smoking
USA	United States of America
UT	Utah

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13690-025-01585-5.

Supplementary Material 1

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Author contributions

: Conceptualization and formal analysis, B.C.F. and D.P.A.; writing the original draft, D.P.A.; methodology and investigation, B.C.F., D.P.A., C.M.M., D.C.R.A., L.L., and C.S.O.; super-vision and visualization, D.P.A., B.C.F., C.S.O., and L.L.; investigation and editing. All au-thors have reviewed the literature and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

We report a retrospective study of archived and fully anonymized data from the SEER and CDC databases. We followed all the required steps for the data release policy and data user agreement of the SEER and CDC. This project was evaluated and approved by the Príncipe Ethics Committee of Pequeno Principe College, Curitiba, Paraná, Brazil, and informed consent was waived.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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