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Risk of Food Insecurity and Stratified difference for Bronchus and lung cancer-related mortality: County-Level Evidence from the United States

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Abstract

Background: Bronchus and lung cancer remains the leading cause of cancer-related mortality in the United States. Although mortality has declined over recent decades, substantial geographic and socioeconomic disparities persist. Food insecurity and poor food environments may represent important contextual determinants of cancer outcomes, but their association with bronchus and lung cancer-related mortality at the county level remains insufficiently investigated.

Methods: County-level bronchus and lung cancer-related mortality data from 1999 to 2024 were obtained from CDC WONDER. Food insecurity percentage (FI%) and Food Environment Index (FEI) were obtained from County Health Rankings. Negative binomial regression models were used to evaluate the associations of FI% and FEI with mortality, with sequential adjustment for demographic, socioeconomic, health-related, environmental and SVI covariates. Stratified temporal trends were further assessed by age, sex, race/ethnicity, and urban–rural status.

Result： From 1999 to 2024, 3,906,674 bronchus and lung cancer-related deaths were recorded among U.S. adults. The overall age-adjusted mortality rate declined significantly, with an average annual percentage change of -2.68% (95% CI: -2.97 to -2.38; $p < 0.01$). Counties with higher FI% and lower FEI generally had greater socioeconomic and health-related vulnerability. After full adjustment, each 1-percentage-point increase in FI% was associated with a 1.17% increase in mortality (95% CI: 0.82%–1.53%; $p < 0.001$), and each 1-unit decrease in FEI was associated with a 4.31% increase in mortality (95% CI: 2.91%–5.71%; $p < 0.001$). Stratified analyses showed declining mortality across major demographic and geographic subgroups, but the magnitude of decline varied.

Conclusion： Higher county-level food insecurity and poorer food environments were independently associated with increased bronchus and lung cancer-related mortality. Incorporating food security and healthy food access into lung cancer prevention strategies may help reduce mortality disparities.

Key words: Bronchus and lung cancer; food insecurity; Food Environment Index; mortality; county-level analysis; health disparities

1. Introduction

Bronchus and lung cancer remains the leading cause of cancer-related mortality in the United States, imposing a substantial and persistent public health burden.[1, 2] Over the past two decades, advances in tobacco control, low-dose computed tomography screening, molecularly targeted therapy, immunotherapy, and multidisciplinary treatment have contributed to declining lung cancer mortality rates.[3–6] However, these improvements have not been experienced equally across populations. Marked disparities in lung cancer outcomes continue to exist across geographic regions, racial

and ethnic groups, age categories, and socioeconomic strata, suggesting that factors beyond tumor biology and individual clinical care may shape mortality risk.[7–9]

Cigarette smoking remains the dominant risk factor for lung cancer, but growing evidence suggests that broader social, economic, and environmental conditions also contribute to disparities in cancer outcomes.[8, 10] County-level factors such as poverty, limited health care access, rurality, environmental exposure, and social vulnerability may interact with individual risk factors to influence lung cancer incidence, treatment access, disease progression, and survival. Among these contextual determinants, food insecurity has received increasing attention as a potentially important but insufficiently studied contributor to cancer disparities.[11]

Food insecurity, defined as limited or uncertain access to sufficient, affordable, and nutritious food, is more common among patients with cancer than in the general population and may adversely affect lung cancer outcomes through poor nutritional status, psychological stress, delayed care, reduced treatment adherence, and worsening comorbidities.[12, 13] Moreover, food-insecure communities often overlap with areas characterized by poverty, higher smoking prevalence, limited medical resources, and reduced access to healthy food outlets. However, few studies have systematically examined whether county-level food insecurity and the broader food environment are associated with bronchus and lung cancer-related mortality across the United States.[14] Therefore, a county-level perspective may help identify structural determinants of mortality and inform public health interventions beyond individual-level smoking prevention and cessation.

Therefore, this study represents the first attempt to evaluate the stratified trends in bronchus and lung cancer-related mortality in the United States from 1999 to 2024, integrating county-level prevalence data on food insecurity.[15] By adjusting for demographic characteristics, including socioeconomic status, smoking prevalence, age, and race/ethnicity. Aiming to reflect the specific impact of food insecurity on lung cancer mortality more accurately. Our findings provide a robust empirical foundation for the formulation of public health policies and offer valuable insights for future interventions for further reducing lung cancer mortality.

2. Method

We obtained county-level data on lung cancer–related mortality in the United States, along with relevant demographic and socioeconomic data, from publicly available/open-access databases. As this study did not involve human subjects research, it was exempt from Institutional Review Board (IRB) approval.[16]

2.1 Data extraction

We obtained county-level lung cancer–related age-adjusted mortality rates (AAMRs) data from CDC WONDER for 1999–2024. Lung cancer cases were identified using

ICD-10 codes C34.0, C34.1, C34.2, C34.3, C34.8, and C34.9. For demographic stratification, we used the same age groups as in previous studies: 25–34, 35–44, 45–54, 55–64, 65–74, 75–84, and 85+ years. Race/ethnicity was categorized as Hispanic, Non-Hispanic (NH) Black, NH White, and NH Other. Urban–rural status was classified according to the NCHS scheme into metropolitan and nonmetropolitan counties. Urban–rural data for 2021–2024 were unavailable, those years were excluded from the analysis.[17] Additionally, CDC suppresses county-level data when the number of deaths is fewer than 20 to protect privacy, rendering such data unavailable.

The primary predictors of mortality included food insecurity (FI%) and the Food Environment Index (FEI). FI% was defined as the proportion of a county's population lacking adequate food access over a 12-month period. This indicator was estimated from self-reported food insecurity status in the Current Population Survey conducted by the US Bureau of Labor Statistics, combined with county-level socioeconomic and demographic data, using a two-stage fixed-effects model. The Food Environment Index is a composite food desert indicator calculated for each US county (range: 0 = worst, 10 = best). It integrates FI% with the proportion of low-income individuals (below 200% of the federal poverty line) who do not live near a grocery store. Given data availability, we used 2018 FI% and FEI data in the regression analysis from County Health Rankings, while corresponding county-level mortality rates were averaged over 2018–2020.

Other covariates included county-level demographic, socioeconomic, and health-related indicators. Demographic variables comprised the proportion of the population aged 65 years and older, female population proportion, and NH White population proportion. Socioeconomic factors included median household income, rural resident proportion, uninsured proportion, population below the poverty line, and average daily PM2.5 concentration. Health-related factors included smoking prevalence and primary care physician (PCP) density. Another covariate of interest was the Social Vulnerability Index (SVI), a composite metric derived from assessments of each county's socioeconomic status, household characteristics, racial composition, and transportation factors. All indicators were sourced from the County Health Rankings, except for the poverty rate (US Census Bureau) and SVI (CDC).

2.2 Statistical analysis

We used mean and standard deviations to describe counties' baseline demographic, socioeconomic, and health-related characteristics. Counties were dichotomized into high and low groups based on the median values of FI% and FEI, respectively, and between-group differences in baseline characteristics were compared using independent samples t-tests. To evaluate the associations of FI% and FEI with county-level tracheal, bronchial, and lung cancer related mortality, we constructed a series of nested negative binomial regression models with sequential adjustment for confounders: Model 1 was unadjusted; Model 2 adjusted for demographic factors; Model 3 adjusted for socioeconomic variables; Model 4 adjusted for health-related covariates; and Model

5 was a fully adjusted model incorporating all covariates. Effect estimates were presented as the relative change in tracheal, bronchial, and lung cancer mortality associated with a 1-percentage-point increase in FI% (indicating worsening food insecurity) and a 1-unit decrease in FEI (indicating intensified food desert conditions). All statistical analyses were conducted using R software (version 4.4.3).

3. Result

3.1 Overall mortality trends and county-level characteristics

During the study period, a total of 3,906,674 bronchus and lung cancer-related deaths were reported. Overall, the AAMR showed a sustained downward trend, decreasing from 85.67 per 100,000 population in 1999 to 43.34 per 100,000 population in 2024, with an average annual percentage change of -2.68% (Table 1, Table 2, Figure 1). Among 3,142 county-level units in the United States, 1,593 counties had complete data available for subsequent analyses of FI% and the FEI. The median and interquartile of FI% and FEI 13.9 (11.7–16.2) and 7.7(7.0–8.2) respectively. Higher FI%, lower FEI, lower median household income, higher average daily PM2.5 concentration, higher SVI, higher poverty prevalence, higher uninsured rate, greater rural population proportion, and higher smoking prevalence had relatively higher bronchus and lung cancer-related mortality rates (Table 3).

3.2 Association between FI% and bronchus and lung cancer-related mortality

Between 2018 and 2020, the mean bronchus and lung cancer-related mortality rate among the included counties was 62.8 ± 23.5 per 100,000 person-years. Bronchus and lung cancer-related mortality increased progressively with higher county-level FI%. The mortality rate increased from 35.7 ± 15.1 per 100,000 person-years in counties with FI% < 5% to 84.3 ± 32.6 per 100,000 person-years in counties with FI% ≥ 20%, with a statistically significant trend across categories (p for trend < 0.001) (Figure 2A).

In negative binomial regression analyses, the unadjusted model showed that each 1-percentage-point increase in FI% was associated with a 2.43% relative increase in bronchus and lung cancer-related mortality (95% CI: 2.14%–2.71%, p < 0.001) (Table 4, Model 1). This association remained significant after adjustment for county-level demographic characteristics (Table 4, Model 2). After further adjustment for socioeconomic factors, health-related factors, and other county-level covariates, the magnitude of the association was attenuated but remained statistically significant. In the fully adjusted model, each 1-percentage-point increase in FI% was associated with a 1.17% relative increase in bronchus and lung cancer-related mortality (95% CI: 0.82%–1.53%, p < 0.001) (Table 4, Model 5).

3.3 Association between FEI and bronchus and lung cancer-related mortality

A significant association was also observed between FEI and bronchus and lung cancer-related mortality. As FEI decreased, county-level bronchus and lung cancer-related

mortality progressively increased. The mortality rate was 42.5 ± 18.7 per 100,000 person-years in counties with FEI ≥ 9.0 and increased to 82.1 ± 28.4 per 100,000 person-years in counties with FEI < 6.0, with a statistically significant trend across categories (Figure 2B).

In the unadjusted model, 1-unit decrease in FEI was associated with an 8.16% relative increase in bronchus and lung cancer-related mortality (95% CI: 6.95%–9.36%, $p < 0.001$) (Table 4, Model 1). This association remained significant after adjustment for demographic characteristics (Table 4, Model 2). With further adjustment for socioeconomic factors, health-related factors, and other county-level covariates, the association between FEI and mortality was attenuated but remained statistically significant. In the fully adjusted model, each 1-unit decrease in FEI was associated with a 4.31% relative increase in bronchus and lung cancer-related mortality (95% CI: 2.91%–5.71%, $p < 0.001$) (Table 4, Model 5).

3.4 Stratified trends in bronchus and lung cancer-related mortality

Across age, sex, race/ethnicity, and urban–rural subgroups, bronchus and lung cancer-related mortality generally showed a declining trend, although the magnitude of decline varied substantially across strata. The whole AAMR distribution across USA is shown in Figure 3. Age-stratified analyses showed that older age groups had higher absolute mortality rates but smaller reductions over time, whereas younger age groups had lower absolute mortality rates but more rapid declines. The most pronounced decreases in age-adjusted mortality were observed among individuals aged 35–44 years and 45–54 years, with annual percentage changes of -5.13% and -4.55%, respectively. In contrast, mortality declined more slowly among individuals aged 75 years and older. (Figure S1, Table S1).

Sex-stratified analyses showed that age-adjusted bronchus and lung cancer-related mortality was consistently higher in men than in women, approximately 1.5–2 times that of women. However, mortality declined more rapidly among men. The AAPC was -3.39% in men and -1.92% in women, and the mortality gap between men and women narrowed from 56.6 per 100,000 population to 11.8 per 100,000 population. Among women, mortality remained largely stable or fluctuated slightly between 1999 and 2007, followed by a sustained decline after 2007. In contrast, mortality among men began to decline continuously from 2001 and reached the greatest rate of decline between 2015 and 2018 (APC: -5.56%) (Figure 1 Table S2).

Race/ethnicity-stratified analyses showed that non-Hispanic Black individuals had the highest initial AAMR, at 101.50 per 100,000 population, but also experienced the most rapid decline. By 2024, the AAMR among NH Black individuals had fallen below that among NH White individuals. Hispanic or Latino individuals consistently had the lowest mortality rate, whereas non-Hispanic individuals of other races had the smallest decline, with an AAPC of -2.22% (Figure S2, Table S3).

Urban–rural stratified analyses showed that age-adjusted bronchus and lung cancer-related mortality was consistently higher in rural areas than in urban areas, and the rate of decline was substantially slower in rural areas. By 2024, the AAMR of urban–rural gap had widened to 16.06. The mortality curves for urban and rural areas showed a clear diverging pattern, suggesting that rural areas lagged substantially behind urban areas in improvements in bronchus and lung cancer-related mortality (Figure S3, Table S4).

4. Discussion

In this county-level study of bronchus and lung cancer-related mortality in the United States, we found that higher FI% and poorer FEI were significantly associated with increased mortality. Although bronchus and lung cancer-related mortality declined nationally from 1999 to 2024, substantial disparities persisted across counties and population subgroups. Importantly, both county-level FI% and the FEI remained significantly associated with mortality after adjustment for demographic characteristics, socioeconomic conditions, health related factors, and SVI. These findings suggest that food-related contextual factors may contribute to geographic disparities in bronchus and lung cancer-related mortality beyond traditional individual-level risk factors.

Several mechanisms may explain the observed association between food insecurity, poor food environments, and higher bronchus and lung cancer-related mortality.[12, 18] Food insecurity may limit access to adequate and nutritious diets, resulting in poorer nutritional status, reduced physiologic reserve, and greater vulnerability during cancer treatment.[19] Patients living in food-insecure settings may also experience financial strain and psychosocial stress, which can delay diagnosis, reduce treatment adherence, and worsen comorbid conditions.[14] In addition, counties with poor food environments often have limited access to grocery stores and healthier foods, while relying more heavily on calorie-dense and highly processed foods.[20] Such dietary patterns may contribute to chronic inflammation, metabolic dysfunction, and impaired immune function, which could adversely influence cancer progression and survival.[21–23]

Persistence of these associations after multivariable adjustment is particularly important. Smoking remains the dominant risk factor for lung cancer, and socioeconomic deprivation, limited health care access, and environmental exposure are also well-recognized contributors to cancer disparities. However, the associations of FI% and FEI with mortality were not fully explained by these factors. This suggests that food insecurity and poor food environments may represent distinct dimensions of structural vulnerability.[24–26] Rather than acting in isolation, they may interact with poverty, rurality, limited medical resources, and behavioral risk factors to increase mortality risk at the population level.[12]

The stratified analyses further showed that reductions in bronchus and lung cancer-related mortality were uneven across demographic and geographic groups. Older adults had higher absolute mortality rates and slower declines, while men experienced faster

reductions than women.[2, 27, 28] Differences were also observed across racial and ethnic groups, census regions, and urban–rural areas. In particular, nonmetropolitan counties had persistently higher mortality and slower improvement than metropolitan counties.[29–31] These patterns provide important context for interpreting the food insecurity findings, as counties with greater food-related vulnerability often overlap with areas characterized by lower income, higher smoking prevalence, reduced health care access, and greater social vulnerability.[14, 18, 32]

These findings have important public health implications. Current lung cancer prevention strategies primarily focus on smoking prevention, smoking cessation, and early detection through low-dose computed tomography screening.[25, 33] Although these approaches remain essential, our results suggest that they may be insufficient to address persistent mortality disparities if broader social and environmental conditions are not considered. Incorporating food security into lung cancer control strategies may help identify high-risk communities and improve intervention targeting.[34, 35] Policies such as expanding nutrition assistance programs, improving access to affordable healthy foods, supporting grocery store development in underserved areas, and integrating nutrition screening into oncology care may complement existing lung cancer prevention and treatment efforts.[11, 36]

This study has several limitations. First, because this was an ecological study based on county-level data, the observed associations cannot be directly interpreted as individual-level causal relationships. Second, county-level aggregated data may mask substantial within-county heterogeneity in food access, socioeconomic conditions, health care resources, and cancer outcomes. Third, food insecurity and food environment data were not available for all counties and years, and the FI% and FEI measures used in the main regression analyses may not fully capture temporal changes in local food environments. Fourth, although we adjusted for multiple demographic, socioeconomic, health-related, and environmental covariates, residual confounding from unmeasured factors, such as cancer stage at diagnosis, treatment access, treatment quality, occupational exposure, and individual dietary patterns, cannot be excluded. Finally, county-level mortality data may be suppressed in areas with small numbers of deaths, which could affect estimates in sparsely populated counties.

5. Conclusion

In conclusion, this county-level study found that higher food insecurity and poorer food environments were independently associated with increased bronchus and lung cancer-related mortality in the United States. These associations persisted after adjustment for major demographic, socioeconomic, behavioral, health care, and environmental factors. Our findings highlight the potential role of food-related structural determinants in lung cancer mortality disparities and suggest that improving food security and healthy food access may serve as a complementary strategy for reducing bronchus and lung cancer-related mortality. Future individual-level and longitudinal studies are needed to confirm

these associations and to evaluate whether nutrition-focused interventions can improve lung cancer outcomes.

6. Declarations

Abbreviations:

AAMR: age-adjusted mortality rate; APC: annual percent change; AAPC: average annual percentage change; CDC: Centers for Disease Control and Prevention; FEI: Food Environment Index; FI%: food insecurity percentage; NH: Non-Hispanic; PCP: primary care physician; PM2.5: fine particulate matter ≤ 2.5 μm in diameter; SVI: Social Vulnerability Index.

Ethics approval and consent to participate

This study was based on publicly available, de-identified, aggregate-level data and did not involve human subjects research. Therefore, it was exempt from Institutional Review Board (IRB) approval. This study was conducted in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

Consent for publication

Not applicable. This study did not involve individual patient data or identifiable personal information.

Availability of data and materials

The datasets analyzed during the current study are publicly available. County-level bronchus and lung cancer-related mortality data were obtained from the CDC WONDER database (https://wonder.cdc.gov). Food insecurity percentage (FI%) and Food Environment Index (FEI) data were obtained from County Health Rankings (https://www.countyhealthrankings.org). Poverty rate data were obtained from the US Census Bureau (https://www.census.gov). Social Vulnerability Index (SVI) data were obtained from the CDC/ATSDR (https://www.atsdr.cdc.gov/placeandhealth/svi/). The R code used for statistical analyses is available from the corresponding authors upon reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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Final approval of manuscript: All authors.

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7. Reference

1. Siegel RL, Miller KD, Fuchs HE, Jemal A (2022) Cancer statistics, 2022. CA Cancer J Clin 72:7–33

2. Hendriks LEL, Remon J, Faivre-Finn C, Garassino MC, Heymach JV, Kerr KM, Tan DSW, Veronesi G, Reck M (2024) Non-small-cell lung cancer. Nat Rev, Dis Primers 10:71

3. Tahayneh K, Idkedek M, Abu Akar F (2025) NSCLC: current evidence on its pathogenesis, integrated treatment, and future perspectives. J Clin Med 14:1025

4. M Z, L S (2025) First-line treatment for advanced or metastatic EGFR mutation-positive non-squamous non-small cell lung cancer: a network meta-analysis. Front Oncol. https://doi.org/10.3389/fonc.2024.1498518

5. Karanth SD, Divaker J, Blair M, et al (2024) Rethinking how mobile units can catalyze progress on lung cancer screening: a scoping review of what we have learned. J Thorac Dis 16:7143–7154

6. Jonas DE, Reuland DS, Reddy SM, et al (2021) Screening for lung cancer with low-dose computed tomography: updated evidence report and systematic review for the US preventive services task force. JAMA 325:971–987

7. Wei M, Wu Y, Li Z, et al (2026) Bronchus and lung cancer-related mortality trends in the United States from 1999 to 2023. J Cardiothorac Surg. https://doi.org/10.1186/s13019-026-04075-z

8. F I, Ec M, B T, Ml M, H R, Sm G, Av P, I S, A J (2024) Proportion and number of cancer cases and deaths attributable to potentially modifiable risk factors in the United States, 2019. CA Cancer J Clin. https://doi.org/10.3322/caac.21858

9. Huang J, Deng Y, Tin MS, et al (2022) Distribution, risk factors, and temporal trends for lung cancer incidence and mortality: a global analysis. Chest 161:1101–1111

10. Cheng I, Yang J, Tseng C, et al (2022) Traffic-related air pollution and lung cancer incidence: the california multiethnic cohort study. Am J Respir Crit Care Med 206:1008–1018

11. Goodenberger KE, Bose S, Murray SK, Bosma CB, Han MK, Curtis JL, Labaki WW (2026) Food insecurity is associated with COPD prevalence and mortality: evidence from U.S. county-level data. Ann Am Thorac Soc aaoag096

12. Raber M, Jackson A, Basen-Engquist K, Bradley C, Chambers S, Gany FM, Halbert CH, Lindau ST, Pérez-Escamilla R, Seligman H (2022) Food insecurity among people with cancer: nutritional needs as an essential component of care. J Natl Cancer Inst 114:1577–1583

13. Lin JC, Sun J, Yan R, Wang LS, McCarthy AM, Tong G, Aysola J (2025) Mortality outcomes for survivors of cancer with food insecurity in the US. JAMA health forum 6:e251381

14. McDougall JA, Anderson J, Adler Jaffe S, Guest DD, Sussman AL, Meisner ALW, Wiggins CL, Jimenez EY, Pankratz VS (2020) Food insecurity and forgone medical care among cancer survivors. JCO oncol pract 16:e922–e932

15. Didier AJ, Roof L, Stevenson J (2024) Demographic disparities in lung cancer mortality and trends in the United States from 1999 through 2020: a population-based CDC database analysis. J Natl Compr Cancer Netw: JNCCN 22:e247004

16. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, STROBE Initiative (2007) The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. Ann Intern Med 147:573–577

17. Ingram DD, Franco SJ (2014) 2013 NCHS urban-rural classification scheme for counties. Vital Health Stat 2 1–73

18. Bossi P, De Luca R, Ciani O, D'Angelo E, Caccialanza R (2022) Malnutrition management in oncology: an expert view on controversial issues and future perspectives. Front Oncol 12:910770

19. Landgrebe M, Tobberup R, Carus A, Rasmussen HH (2023) GLIM diagnosed malnutrition predicts clinical outcomes and quality of life in patients with non-

small cell lung cancer. Clin Nutr 42:191–198

20. P B, R DL, O C, E D, R C (2022) Malnutrition management in oncology: an expert view on controversial issues and future perspectives. Front Oncol. https://doi.org/10.3389/fonc.2022.910770

21. Mm L, E G, S D, et al (2024) Ultra-processed food exposure and adverse health outcomes: umbrella review of epidemiological meta-analyses. BMJ (Clin res ed,). https://doi.org/10.1136/bmj-2023-077310

22. Castro-Espin C, Bonet C, Crous-Bou M, et al (2023) Dietary patterns related to biological mechanisms and survival after breast cancer diagnosis: results from a cohort study. Br J Cancer 128:1301–1310

23. Mercier BD, Tizpa E, Philip EJ, Feng Q, Huang Z, Thomas RM, Pal SK, Dorff TB, Li YR (2022) Dietary interventions in cancer treatment and response: a comprehensive review. Cancers (Basel) 14:5149

24. Brock BA, Mir H, Flenaugh EL, Oprea-Ilies G, Singh R, Singh S (2024) Social and biological determinants in lung cancer disparity. Cancers 16:612

25. L E, Se W, X Z, P C, Jr P, F LW (2022) Neighborhood disadvantage and lung cancer risk in a national cohort of never smoking black women. Lung cancer (Amst Neth). https://doi.org/10.1016/j.lungcan.2022.08.022

26. Lin JC, Sun J, Yan R, Wang LS, McCarthy AM, Tong G, Aysola J (2025) Mortality outcomes for survivors of cancer with food insecurity in the US. JAMA Health Forum 6:e251381

27. N M, A F, S P, A A (2020) Gender-specific aspects of epidemiology, molecular genetics and outcome: lung cancer. ESMO Open. https://doi.org/10.1136/esmoopen-2020-000796

28. John U, Hanke M (2015) Lung cancer mortality and years of potential life lost among males and females over six decades in a country with high smoking prevalence: an observational study. BMC Cancer 15:876

29. Sr G, Ta L, Ab M, et al (2020) Racial and ethnic disparities among participants in US-based phase 3 randomized cancer clinical trials. JNCI Cancer Spectr. https://doi.org/10.1093/jncics/pkaa060

30. James BA, Williams JL, Nemesure B (2023) A systematic review of genetic ancestry as a risk factor for incidence of non-small cell lung cancer in the US. Front Genet 14:1141058

31. Bhatia S, Landier W, Paskett ED, Peters KB, Merrill JK, Phillips J, Osarogiagbon RU (2022) Rural-urban disparities in cancer outcomes: opportunities for future

research. J Natl Cancer Inst 114:941–952

32. X W, J Z, Y Y (2025) Disentangling the effects of various risk factors and trends in lung cancer mortality. Sci Rep. https://doi.org/10.1038/s41598-025-92373-2

33. Zhu S-H, Anderson CM, Zhuang Y-L, Sung H-Y, Gamst AC (2025) Association of a major tobacco tax increase in california with increased smoking cessation. J Natl Cancer Inst 117:1883–1890

34. Shin D, Fishman MDC, Ngo M, Wang J, LeBedis CA (2022) The impact of social determinants of health on lung cancer screening utilization. J Am Coll Radiol: JACR 19:122–130

35. Sina EM, Rowe M, Mancuso G, Garber G, Kelly WK, Leader AE (2024) Evaluating the impact of a novel program to address acute food insecurity among cancer patients. Nutrients 16:4408

36. A O-Y, Agm B, T A-C, K G (2024) Food insecurity, neighborhood food environment, and health disparities: state of the science, research gaps and opportunities. Am J Clin Nutr. https://doi.org/10.1016/j.ajcnut.2023.12.019

8. Legends

Table 1 Overall Bronchus and Lung Cancer-related deaths Adults in the United States, 1999 to 2024

Table 2 Annual Percentage Changes (APCs) and Average Annual Percentage Changes (AAPCs) in Bronchus and Lung Cancer-related mortality in the United States from 1999 to 2024.

Table 3. USA County Characteristics

Table 4. Associations of county-level food insecurity (FI%) and Food Environment Index (FEI) with Bronchus and Lung Cancer-related mortality

Figure 1. The AAMR per 100,000 adults of Bronchus and lung cancer, stratified by sex in the United States between 1999 and 2024. AAMR, age-adjusted mortality rate; APC, annual percent change; *, APC was found to be statistically significant at $\alpha < 0.05$

Figure 2. Bronchus and lung cancer related mortality by county food insecurity percent (A) and Food Environment Index (B). The height of each bar represents the mean number of Bronchus and lung cancer related deaths per 100,000 person years (blue) $\pm$ one standard deviation (yellow error bar).

Figure 3. Figure A, The AAMR per 100,000 of Bronchus and lung cancer of the District of Columbia, all 50 states in the United States between 1999 and 2020. Figure B , The AAMR per 100,000 EC of the District of Columbia, all 50 states in the United States between 2018 and 2024. AAMR, age-adjusted mortality rate; APC, annual percent change; (In the CDC WONDER database, the data for each state was segmented into 1999-2020 and 2018-2024 during data extraction, making it unable to obtain the overall AAMR for 1999-2024. Therefore, the AAMRs for these two periods is presented separately.)

Supplementary Figure 1: The crude mortality rate per 100,000 adults of Bronchus and lung cancer, stratified by age group in the United States between 1999 and 2024. APC, annual percent change; *, APC was found to be statistically significant at $\alpha < 0.05$

Supplementary Figure 2. The AAMR per 100,000 adults of Bronchus and lung cancer stratified by race/ethnicity in the United States between 1999 and 2024. AAMR, age-adjusted mortality rate; APC, annual percent change; *, APC was found to be statistically significant at $\alpha < 0.05$

Supplementary Figure 4. The AAMR per 100,000 adults of Bronchus and lung cancer, stratified by urban-rural in the United States between 1999 and 2024. AAMR, age-adjusted mortality rate; APC, annual percent change; *, APC was found to be statistically significant at $\alpha < 0.05$

Supplementary Table1 Crude Mortality Rate per 100,100 adults of Bronchus and Lung Cancer in the United States stratified by age groups, 1999 to 2024

Supplementary Table2 Bronchus and Lung Cancer-related Mortality per 1,000,000 Adults in the United States stratified by sex, 1999 to 2024

Supplementary Table3. Bronchus and Lung Cancer-related Mortality per 1,000,000 Adults in the United States stratified by race, 1999 to 2024

Supplementary Table 4 Bronchus and Lung Cancer-related Mortality in the United States stratified by urban-rural, 1999 to 2020

9. Tables and Figures

Table 1. Overall Bronchus and Lung Cancer-related deaths Adults in the United States, 1999 to 2024

Characteristic	Deaths	%
Age group (years)		
25-34	3,604	0.09
35-44	39,243	1.00
45-54	248,089	6.35
55-64	763,238	19.54
65-74	1,251,449	32.03

75-84	1,161,862	29.74
85+	439,189	11.24
Sex		
Male	2,158,714	44.74
Female	1,747,960	55.26
Race/Ethnicity		
Hispanic or Latino	123,337	3.32
Non-Hispanic White	3,154,263	83.55
Non-Hispanic Black	394,218	10.47
Non-Hispanic Other	98,214	2.66
Census region		
Midwest	913,129	24.18
Northeast	689,493	18.19
South	1,526,697	40.47
West	648,721	17.16
Urban–Rural*		
Metropolitan	2,694,739	79.72
Nonmetropolitan	685,382	20.28

* Due to missing urban-rural data for 2021–2024, the corresponding stratified analyses for these years were not conducted in this study

Table 2 Annual Percentage Changes (APCs) and Average Annual Percentage Changes (AAPCs) in Bronchus and Lung Cancer-related mortality in the United States from 1999 to 2024.

Variable	Lower Endpoint – Upper Endpoint	APC (95% CI)	P-value	AAPC (95% CI)	P-value
Overall	1999 – 2002	-0.26 (-1.49–0.99)	0.66	-2.68 (-2.97 to -2.38)	<0.01
	2002 – 2010	-1.84 (-2.17 to -1.52)	<0.01		
	2010 – 2014	-3.01 (-4.21 to -1.80)	<0.01		
	2014 – 2019	-4.59 (-5.37 to -3.82)	<0.01		
	2019 – 2024	-3.22 (-3.81 to -2.63)	<0.01		
Sex					
Male	1999 – 2001	-0.93 (-3.01–1.18)	0.35	-3.39 (-3.71 to -3.07)	<0.01
	2001 – 2010	-2.48 (-2.71 to -2.25)	<0.01		
	2010 – 2015	-3.83 (-4.49 to -3.17)	<0.01		
	2015 – 2018	-5.56 (-7.67 to -3.40)	<0.01		
	2018 – 2024	-4.10 (-4.49 to -3.71)	<0.01		
Female	1999 – 2002	0.89 (-0.66–2.47)	0.24	-1.92 (-2.26 to -1.58)	<0.01
	2002 – 2007	-0.75 (-1.69–0.19)	0.11		
	2007 – 2014	-1.96 (-2.45 to -1.46)	<0.01		
	2014 – 2019	-4.24 (-5.16 to -3.31)	<0.01		
	2019 – 2024	-2.36 (-3.05 to -1.67)	0.01		
Race/Ethnicity					
Hispanic or Latino	1999 – 2014	-2.12 (-2.33 to -1.90)	<0.01	-2.71 (-3.25 to -2.17)	<0.01
	2014 – 2017	-5.66 (-9.89 to -1.23)	0.02		
	2017 – 2024	-2.70 (-3.29 to -2.12)	<0.01		
NH Black	1999 – 2004	-1.59 (-2.08 to -1.10)	<0.01	-3.06 (-3.24 to -2.87)	<0.01
	2004 – 2013	-2.58 (-2.81 to -2.34)	<0.01		
	2013 – 2020	-4.92 (-5.29 to -4.55)	<0.01		
	2020 – 2024	-2.64 (-3.38 to -1.89)	<0.01		
NH White	1999 – 2001	0.61 (-1.81–3.09)	0.6	-2.37 (-2.66 to -2.08)	<0.01
	2001 – 2008	-1.31 (-1.71 to -0.91)	<0.01		
	2008 – 2014	-2.49 (-3.02 to -1.95)	<0.01		
	2014 – 2019	-4.36 (-5.13 to -3.58)	<0.01		
	2019 – 2024	-2.89 (-3.48 to -2.29)	<0.01		
NH Other	1999 – 2011	-0.82 (-1.13 to -0.50)	<0.01	-2.22 (-2.40 to -2.05)	<0.01
	2011 – 2024	-3.51 (-3.72 to -3.29)	<0.01		
Census Region					
Midwest	1999 – 2007	-0.66 (-0.98 to -0.34)	<0.01	-2.20 (-2.46 to -1.93)	<0.01
	2007 – 2014	-2.06 (-2.54 to -1.58)	<0.01		
	2014 – 2019	-4.29 (-5.20 to -3.37)	<0.01		
	2019 – 2024	-2.71 (-3.40 to -2.02)	<0.01		
Northeast	1999 – 2002	-0.56 (-1.80–0.69)	0.34	-2.86 (-3.16 to -2.57)	<0.01
	2002 – 2010	-1.68 (-2.02 to -1.35)	<0.01		
	2010 – 2015	-3.12 (-3.92 to -2.32)	<0.01		
	2015 – 2020	-5.15 (-5.98 to -4.32)	<0.01		
	2020 – 2024	-3.68 (-4.58 to -2.77)	<0.01		

South	1999 – 2005	-0.93 (-1.40 to -0.46)	<0.01	-2.69 (-2.93 to -2.46)	<0.01
	2005 – 2013	-2.46 (-2.82 to -2.10)	<0.01		
	2013 – 2019	-4.37 (-4.97 to -3.76)	<0.01		
	2019 – 2024	-3.15 (-3.79 to -2.50)	<0.01		
West	1999 – 2009	-2.14 (-2.42 to -1.87)	<0.01	-3.28 (-3.75 to -2.81)	<0.01
	2009 – 2015	-3.73 (-4.50 to -2.95)	<0.01		
	2015 – 2018	-5.72 (-9.18 to -2.13)	<0.01		
	2018 – 2024	-3.48 (-4.12 to -2.84)	<0.01		
Urban-Rural					
Metropolitan	1999 – 2001	-0.36 (-1.40–0.70)	<0.01	-2.83 (-2.99 to -2.66)	<0.01
	2001 – 2005	-1.53 (-2.04 to -1.02)	<0.01		
	2005 – 2010	-2.24 (-2.56 to -1.91)	<0.01		
	2010 – 2014	-3.08 (-3.59 to -2.57)	<0.01		
	2014 – 2020	-4.79 (-4.97 to -4.61)	<0.01		
Nonmetropolitan	1999 – 2001	1.40 (-0.68 – 3.52)	0.17	-1.73 (-1.97 to -1.48)	<0.01
	2001 – 2008	-0.78 (-1.12 – -0.44)	<0.01		
	2008 – 2014	-1.86 (-2.31 – -1.42)	<0.01		
	2014 – 2020	-3.70 (-4.04 – -3.35)	<0.01		

Table 3. USA County Characteristics

Characteristic	FI% ≥ 13.9% (n =799)	FI% < 13.9% (n=794)	p-value	FEI < 7.7（768）	FEI ≥ 7.7（825）	p-value
% with age ≥ 65 years	17.19	16.82	0.1872	17.01	16.97	0.8568
% female	50.89	50.50	<0.001	50.885	50.510	<0.001
% non-Hispanic white	85.885	74.67	<0.001	73.225	86.530	<0.001
% living in rural area	45.53	37.95	<0.001	41.415	42.780	0.5633
% uninsured	12.63	8.11	<0.001	12.575	8.360	<0.001
% living below poverty line	18.00	11.65	<0.001	17.80	11.90	<0.001
Median household income (k$)	43683.0	56297.5	<0.001	44451.0	56011.0	<0.001
Average daily PM2.5 (µg/m3)	9.6	9.7	0.06691	9.60	9.65	0.1333
% currently smoking cigarettes	19.720	16.435	<0.001	19.475	16.620	<0.001
PCP density (per 100k population)	53.305	57.675	0.005821	55.300	56.350	0.1291
Social Vulnerability Index	0.708	0.332	<0.001	0.71145	0.34810	<0.001

Values represent the mean (standard deviation) for each characteristic. FI%: county food insecurity percentage (dichotomized at the median of 13.2%); FEI: county food environment index (dichotomized at the median of 7.6 units); PM2.5: fine particulate matter ≤ 2.5 µm in diameter; PCP: primary care physician.

Table 4. Associations of county-level food insecurity (FI%) and Food Environment Index (FEI) with Bronchus and Lung Cancer-related mortality

Model	Relative increase in COPD prevalence per 1% increase in FI%		Relative increase in COPD prevalence per 1 unit decrease in FEI	
	Estimate (95% CI)	p-value	Estimate (95% CI)	p-value
Model 1 (univariable)	2.43 (2.14-2.71)	<0.001	8.16 (6.95–9.36)	<0.001
Model 2 (adjusted for demographic factors)	3.52 (3.25-3.79)	<0.001	12.86 (11.68–14.04)	<0.001
Model 3 (adjusted for socioeconomic factors)	1.43 (1.06-1.81)	<0.001	5.69 (4.22–7.15)	<0.001
Model 4 (adjusted for health-related factors)	1.14 (0.79-1.49)	<0.001	4.16 (2.76–5.57)	<0.001
Model 5 (fully adjusted model)	1.17 (0.82-1.53)	<0.001	4.31 (2.91–5.71)	<0.001

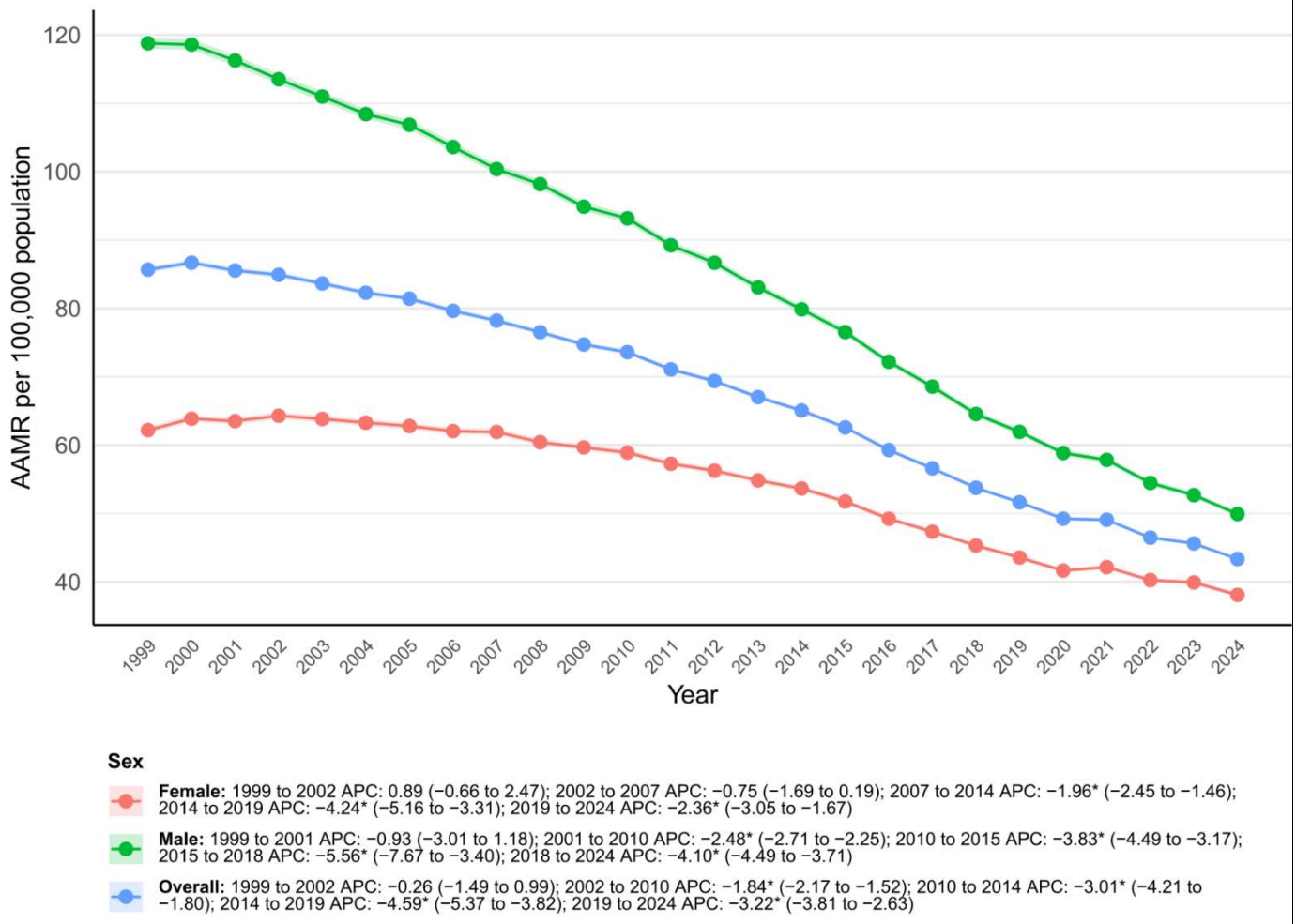
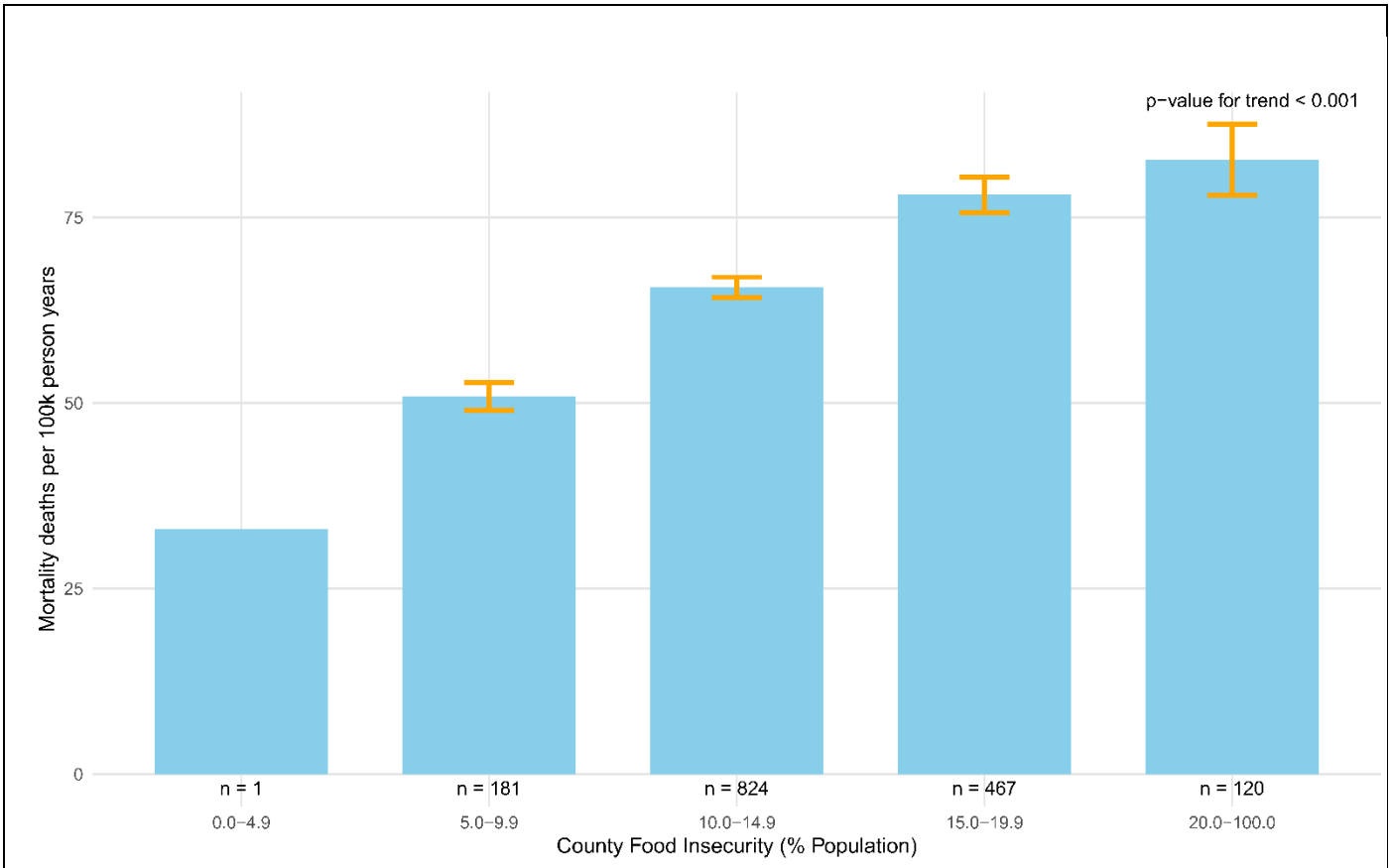


Figure 1. The AAMR per 100,000 adults of Bronchus and lung cancer, stratified by sex in the United States between 1999 and 2024. AAMR, age-adjusted mortality rate; APC, annual percent change; *, APC was found to be statistically significant at $\alpha < 0.05$



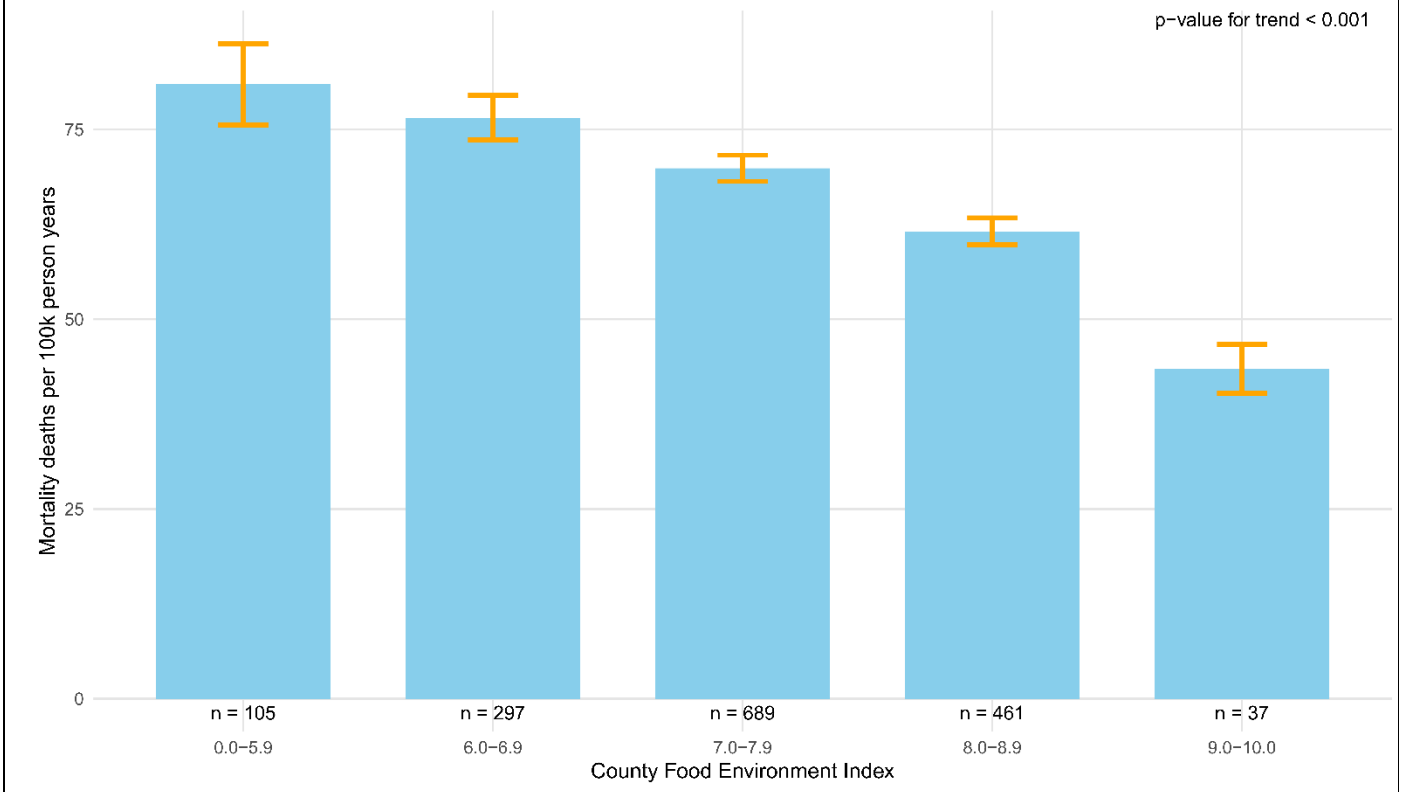


Figure 2. Bronchus and lung cancer related mortality by county food insecurity percent (A) and Food Environment Index (B). The height of each bar represents the mean number of Bronchus and lung cancer related deaths per 100,000 person years (blue)

± one standard deviation (yellow error bar).

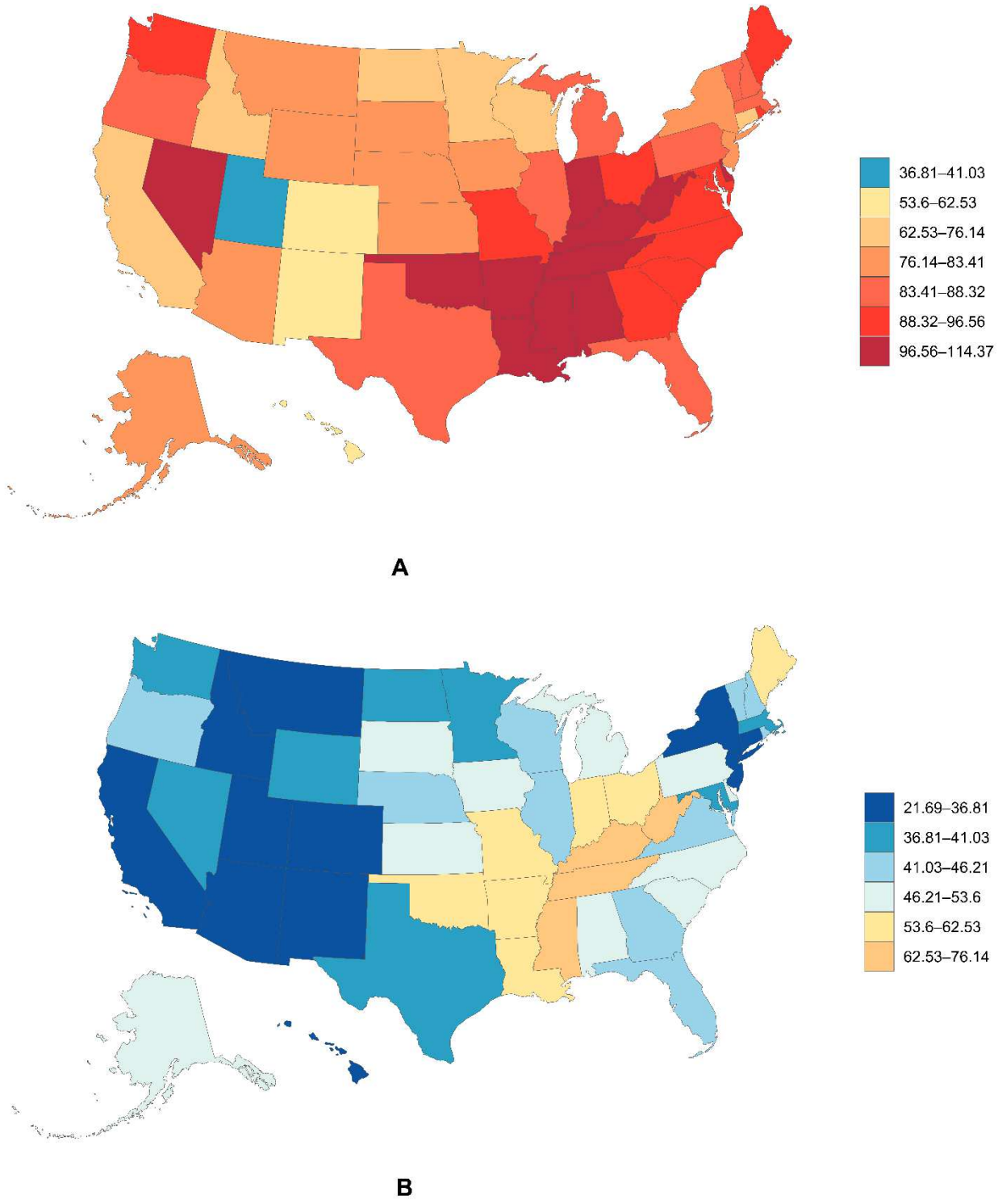


Figure 3. Figure A, The AAMR per 100,000 of Bronchus and lung cancer of the District of Columbia, all 50 states in the United States between 1999 and 2020. Figure B , The AAMR per 100,000 EC of the District of Columbia, all 50 states in the United

States between 2018 and 2024. AAMR, age-adjusted mortality rate; APC, annual percent change; (In the CDC WONDER database, the data for each state was segmented into 1999-2020 and 2018-2024 during data extraction, making it unable to obtain the overall AAMR for 1999-2024. Therefore, the AAMRs for these two periods is presented separately.)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFigure13.pdf
- SupplementaryTable14.docx