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Lung cancer disparities in rural, persistent poverty counties: a secondary data analysis

Veronica Bernacchi[1*], Kelly Hirko[2], Eric Adjei Boakye[3], Samantha Tam[3], Todd Lucas[4] and Jennifer L. Moss[5]

Abstract

Background In the US, lung cancer burden is greater in counties that are either rural or in persistent poverty. This study examined lung cancer risk (e.g., smoking), incidence, and mortality across four county types defined by cross-classification of rurality and persistent poverty.

Methods We conducted a secondary analysis of county characteristics and lung cancer risk, incidence and mortality. We used data from USDA to classify counties according to rurality (using rural–urban continuum codes) and persistent poverty (i.e., 20% + of residents living below the poverty line for 30 + years). We used publicly-available data to calculate mean county-level prevalence of smoking among adults (in 2019), lung cancer incidence (2015–2019), and lung cancer mortality (2015–2019) across county types. Beta and binomial regression models assessed differences in smoking, lung cancer incidence, and lung cancer mortality by rurality and persistent poverty.

Results Among U.S. counties, 1,115 were urban, non-persistent poverty, 1,675 were rural, non-persistent poverty, 52 were urban, persistent poverty, and 301 were rural, persistent poverty. Smoking, lung cancer incidence, and lung cancer mortality were higher in rural counties and in persistent poverty counties than in their comparison counties. Counties that were both rural and persistent poverty had the highest rates of smoking, lung cancer incidence, and lung cancer mortality. Persistent poverty and rurality interacted in their relationship with smoking prevalence ($p < 0.01$), and lung cancer mortality ($p < 0.10$).

Conclusions Smoking, lung cancer incidence, and lung cancer mortality are highest in counties that are both rural and persistent poverty, suggesting an urgent need to develop targeted lung cancer interventions in these communities.

Keywords Persistent povety, Rural, Lung cancer, Cancer disparities

Background

Overall cancer mortality in US rural counties is ~ 10% higher compared to urban counties [1]. This disparity is due to adverse, multilevel (individual, social, environmental) factors impacting cancer risk, incidence, and mortality for individuals residing in rural counties. For example, smoking, a significant risk factor for cancer, is more prevalent in rural areas [2], and contributes to increased lung cancer incidence in rural counties [3]. Limited healthcare access in rural counties also contributes to disparities in cancer screening and treatment opportunities [4, 5]. Rural populations tend to face longer travel distances to healthcare facilities and often reside in

*Correspondence:
Veronica Bernacchi
bernacc3@msu.edu
[1] Michigan State University College of Nursing, 1355 Bogue St, East Lansing, MI 48823, USA
[2] Department of Epidemiology and Biostatistics, Michigan State College of Human Medicine, East Lansing, MI, USA
[3] Department of Otolaryngology, Henry Ford Cancer Institute, Detroit, MI, USA
[4] Department of Public Health, Michigan State University College of Human Medicine, Flint, MI, USA
[5] Department of Family and Community Medicine, Penn State College of Medicine, Hershey, PA, USA

areas with a scarcity of local healthcare providers [6–10]. Individuals diagnosed with cancer in rural regions also experience barriers related to accessing healthcare services due to higher rates of uninsurance compared to those residing in urban settings [11]. Cancer screening and treatment disparities then impact rural–urban differences in survival rates [1, 5].

Besides rurality, another county-level predictor of poor cancer outcomes is persistent poverty (i.e., counties with poverty rates of 20% or greater for 30 + years) [12]. Overall cancer mortality is 12.3% higher in persistent poverty compared to non-persistent poverty counties [13]. Like rural counties, persistent poverty counties face adverse, multilevel determinants that impact the cancer control continuum. For example, persistent poverty counties have fewer healthcare resources, greater unemployment, and increased exposure to cancer risk factors and behaviors (e.g., smoking, alcohol) [13, 14].

Although disparities in rural counties and for high poverty counties are observed for many types of cancer, lung cancer disparities are especially pernicious. Notably, lung cancer mortality is ~ 20% higher in rural counties than urban ones [1], and is 16.5% higher in persistent poverty counties than non-persistent poverty counties [13]. Based on these data, we hypothesize that lung cancer risk, incidence and mortality disparities will be greatest in counties that are both rural and persistent poverty. Testing this hypothesis will provide a novel understanding of county-level lung cancer risk, incidence and mortality across the cancer continuum by the interaction of rurality and persistent poverty. Understanding the interaction between rurality and persistent poverty can offer insight into populations at the greatest risk of lung cancer risk, incidence and mortality and potential mechanistic pathways increasing lung cancer risk, incidence, and mortality.

In this study, we jointly consider rurality and persistent poverty to identify populations that may be especially vulnerable to lung cancer. We hypothesized that rurality and persistent poverty would interact to contribute to worse lung cancer risk, incidence and mortality. The study approach can guide future studies investigating the interaction between rurality and persistent poverty for other health disparities, and findings can be used to guide the strategic development and implementation of population-level interventions ameliorating lung cancer disparities. Jointly evaluating rurality and poverty may also suggest strategies to develop and implement novel cancer control interventions.

Methods

We conducted an ecologic, correlational secondary data analysis of existing, publicly-available, national data sources to examine the interaction between rurality and persistent poverty counties and their impact on lung cancer risk, incidence and mortality. This study was determined to be exempt by the Michigan State University Institutional Review Board.

Measures

We classified counties as persistent poverty or non-persistent poverty using the US Department of Agriculture (USDA) definition of persistent poverty for 1980 through 2007–11 [12]. Specifically, persistent poverty counties are those in which 20% of more of the population has lived below the poverty line according to the 1980, 1990, and 2000 census measures [12], and the 2007–11 American Community Survey data [15]. Further, we used the USDA Rural–Urban Continuum Codes (RUCC) to classify counties as urban (RUCC = 1–3) or rural (RUCC = 4–9) [16]. In addition to the separate classifications, we created a cross-classification of these variables for four mutually-exclusive county types (urban, non-persistent poverty; urban, persistent poverty; rural, non-persistent poverty; and rural, persistent poverty).

We accessed county-level smoking prevalence via the 2022 County Health Rankings and Roadmaps data, which is a publicly-available national dataset with measures of health indicators from counties across the US. Smoking prevalence was measured as the percent of adults who were current smokers according to the 2019 Behavioral Risk Factor Surveillance System [15].

In addition, we accessed the 2015–2019 county-level, age-adjusted lung cancer incidence and mortality counts and rates from the National Cancer Institute's State Cancer Profiles [17]. Lung cancer incidence rates are expressed as the number of new cases of lung cancer per 100,000 people per year. Lung cancer mortality rates are expressed as the number of lung cancer deaths per 100,000 people per year.

We assessed key county-level covariates from the 2022 County Health Rankings and Roadmaps data that may contribute to geographic disparities in lung cancer risk, incidence, and mortality. These covariates were chosen a priori to data analysis based on prior literature [12, 13, 18–20] to control for their potential influence on lung cancer risk, incidence and mortality [21]. Access to primary care was operationalized as the density of primary care physicians per 1,000 population [15]. Health insurance coverage was operationalized as the percent of adults under 65 years of age without health insurance [15]. Racial/ethnic composition was expressed as percentage of the county population identifying as non-Hispanic White [15], and US Census regions were categorized as Midwest, Northeast, South, and West [22].

Statistical analysis

We ran descriptive analyses for study variables to characterize key study variables across the four county types (urban/non-persistent poverty, urban/persistent poverty, rural/non-persistent poverty, rural/persistent poverty). We used unadjusted ANOVA tests to assess differences in smoking, lung cancer incidence and mortality across county types, and examined pairwise differences in smoking prevalence, lung cancer incidence and mortality with post hoc Tukey tests.

Our inferential analysis examined associations between rurality, persistent poverty, and lung cancer risk (e.g., smoking) and outcomes (lung cancer incidence, and lung cancer mortality). We used multivariable beta regression models to evaluate the relationships between rurality, persistent poverty, and control variables with smoking. We used multivariable Poisson regression models to evaluate the relationship between rurality, persistent poverty, and control variables with lung cancer incidence and mortality. Then, we examined potential interactions between rurality and persistent poverty in their relationship with lung cancer risk, incidence and mortality. We built multivariable models with multiplicative interaction terms between rurality and persistent poverty, which we evaluated with Wald chi-square tests. When the interaction term was statistically significant, we reran the regression models to assess differences in the relationship between rurality and lung cancer risk, incidence, and mortality stratified by persistent poverty. Models also controlled for density of primary care providers, racial/ethnic composition, health insurance coverage, and region. All statistical analyses were conducted in SAS version 9.4 using a $p < 0.05$, except the tests of statistical interaction, which used a more liberal $p < 0.10$, because interaction analysis are typically underpowered [23].

Results

A total of 3,143 US counties were examined. Of these, 1675 (53.3%) counties were rural, non-persistent poverty, 301 (9.6%) counties were rural, persistent poverty 1,115 (35.5%) counties were urban, non-persistent poverty, 52 (1.7%) counties were urban, persistent poverty. The density of primary care providers varied from 0.38 in rural, persistent poverty counties to 0.62 providers per 1000 population in urban, non-persistent poverty counties to, while the percentage of uninsured individuals varied from 10.4% in urban, non-persistent poverty counties to 15.0% in rural, persistent poverty counties. The percentage of non-Hispanic White population in the counties varied from 46.5% in urban, persistent poverty counties, to 81.4% in rural, non-persistent poverty counties. The Southern region had high concentrations of rural, persistent poverty counties (83.7%) and urban, persistent poverty counties (82.7%). Demographic characteristics of the different county types are depicted in Table 1.

Smoking prevalence by rurality and persistent poverty

Overall, the prevalence of current smoking was 20.4% (95% confidence interval [CI]: 20.2–20.5), which ranged from 18.8% (95% CI: 18.6%–18.9%) in urban, non-persistent poverty counties to 25.4% (95% CI: 24.9.%–25.9%) in rural, persistent poverty counties (Fig. 1). The ANOVA test indicated that smoking prevalence differed across county types (F-statistic = 261.6, $p < 0.001$). Post hoc tests revealed that urban, non-persistent poverty counties had lower smoking rates than urban, persistent poverty counties ($p < 0.05$), and urban, non-persistent poverty, rural, non-persistent poverty, and urban, persistent poverty counties had lower smoking rates than rural, persistent poverty counties (all $p < 0.05$).

The multivariable model demonstrated that the prevalence of smoking was higher in rural counties compared to urban counties (estimate = 0.11, SE = 0.01, $p < 0.001$), as

Table 1 Demographic characteristics of county types

Variable	Mean (Confidence Interval)				
	Overall	Urban, non-Persistent Poverty ($n = 1115$)	Urban, Persistent Poverty ($n = 52$)	Rural, non-Persistent Poverty ($n = 1675$)	Rural, Persistent Poverty ($n = 301$)
Density of primary Care Providers per 1000 residents	0.51 (0.50, 0.53)	0.62 (0.59, 0.65)	0.52 (0.41, 0.64)	0.47 (0.44, 0.49)	0.38 (0.35, 0.41)
% Uninsured	11.9 (11.8, 12.1)	10.4 (10.2, 10.7)	15.0 (13.1, 16.7)	12.3 (12.1, 12.6)	15.0 (14.4, 15.5)
%Non-Hispanic White	75.5 (74.8, 76.2)	73.6 (72.6, 74.7)	46.5 (39.9, 53.0)	81.4 (80.7, 82.2)	54.4 (51.5, 57.5)
US Region	**County Frequency**				
Midwest	1055 (33.6%)	298 (26.7%)	4 (7.7%)	724 (43.2%)	29 (9.6%)
Northeast	217 (6.9%)	127 (11.4%)	3 (5.8%)	87 (5.2%)	0 (0.0%)
South	1423 (45.3%)	550 (49.3%)	43 (82.7%)	578 (34.5%)	252 (83.7%)
West	448 (14.3%)	140 (12.6%)	2 (3.8%)	286 (17.1%)	20 (6.6%)

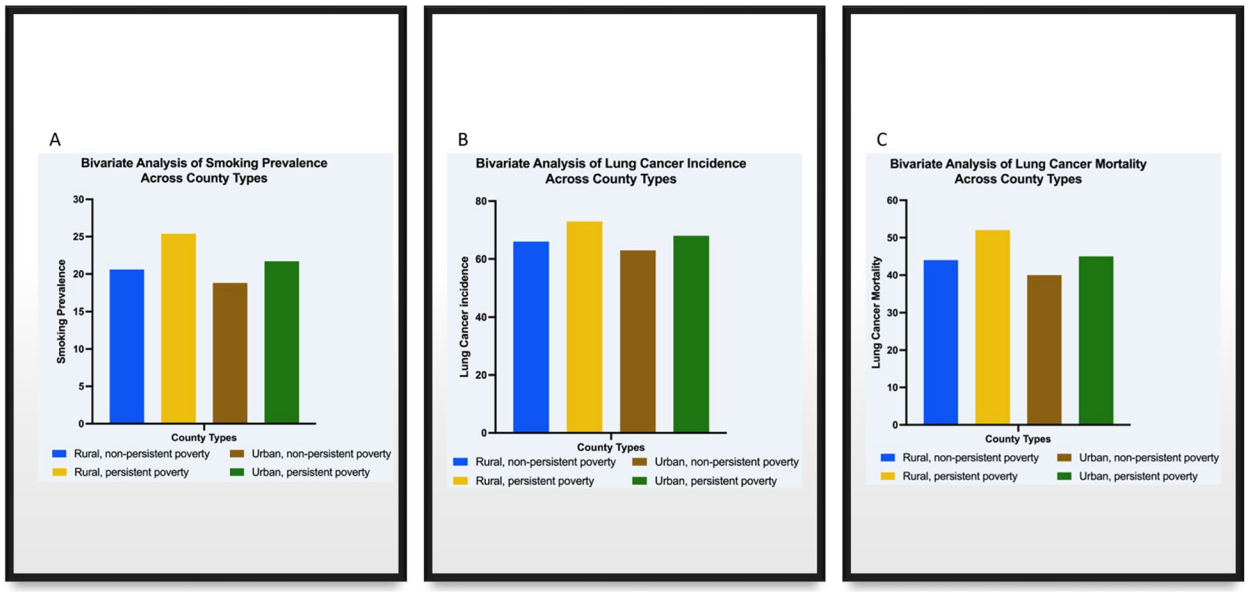

Fig. 1 County-level **A** smoking prevalence—percent current smokers in county **B** lung cancer incidence per 100,000 people/year **C** lung cancer mortality per 100,000 people/year by rurality and persistent poverty

well as in persistent poverty counties compared to non-persistent poverty counties (estimate = 0.26, SE = 0.01, $p < 0.001$) (Table 2). Further, the relationship between rurality and smoking prevalence varied by persistent poverty (interaction $p < 0.03$), such that for non-persistent poverty counties, rurality was associated with higher smoking (estimate = 0.13, SE = 0.01, $p < 0.001$), and for persistent poverty counties, this relationship was even stronger (estimate = 0.20, SE = 0.04, $p < 0.001$). Stratified results for significant interactions between rurality and persistent poverty are depicted in Table 3.

Lung cancer incidence rates by rurality and persistent poverty

Overall, lung cancer incidence was 65.9 cases/100,000 people/year (95% CI: 64.9–66.3), ranging from lowest in urban, non-persistent poverty counties (mean = 63.3 cases/100,000 people/year, 95% CI: 62.3–64.2), to highest

Table 2 Multivariable correlates of county-level smoking, lung cancer incidence, and lung cancer mortality in the United States

	Smoking			Lung Cancer Incidence			Lung Cancer Mortality		
Variable	**Estimate**	**SE**	***P***	**Estimate**	**SE**	***P***	**Estimate**	**SE**	***P***
Rurality									
Urban	(reference)								
Rural	0.11	0.01	< 0.001	3.57	0.67	< 0.001	3.99	0.46	< 0.001
Persistent Poverty									
Not persistent-poverty	(reference)								
Persistent Poverty	0.26	0012	< 0.001	3.84	0.96	< 0.001	3.59	0.67	< 0.001
Density of primary care providers	-0.073	0.01	< 0.001	-9.49	0.73	< 0.001	-8.00	0.49	< 0.001
Percent uninsured	0.12	0.09	0.21	-69.53	6.01	< 0.001	-28.17	4.06	< 0.001
% non-Hispanic White	0.38	0.02	< 0.001	24.19	1.21	< 0.001	16.57	0.84	< 0.001
Region									
Midwest	(reference)								
Northeast	-0.02	0.02	0.14	-2.82	0.68	< 0.001	-4.45	0.46	< 0.001
South	0.13	0.01	< 0.001	3.96	0.66	< 0.001	2.37	0.44	< 0.001
West	-0.17	0.01	< 0.001	-14.37	0.66	< 0.001	-7.50	0.45	< 0.001

Table 3 Relationships between rurality and smoking and lung cancer mortality, stratified by persistent poverty

	Smoking			Lung Cancer Mortality		
	Est	**SE**	***P***	**Est**	**SE**	***P***
Non-persistent poverty						
Rurality						
Urban	ref			ref		
Rural	1.13	0.01	< 0.001	10.16	0.55	< 0.001
Persistent poverty						
Rurality						
Urban	ref			ref		
Rural	0.20	0.04	< 0.001	18.81	1.66	< 0.001

in rural, persistent poverty counties (mean = 73.1, 95% CI: 70.3–75.8) (Fig. 1). The ANOVA test indicated that lung cancer incidence differed across county types (F-statistic 22.46, $p < 0.001$). The post hoc Tukey test indicated that rural, persistent poverty counties had higher mean incidence rates than rural, non-persistent poverty ($p = 0.05$) and urban, non-persistent poverty counties (63.3/100,000 people/year; $p = 0.07$), and rural, non-persistent poverty counties had higher rates than urban, persistent poverty counties ($p < 0.01$).

In multivariable analysis, lung cancer incidence was higher in rural counties compared to urban counties (estimate = 3.57, SE = 0.67, $p < 0.001$) (Table 2). Lung cancer incidence was also higher in persistent poverty counties compared to non-persistent poverty counties (estimate = 3.84, SE = 0.96, $p < 0.001$). Rurality and persistent poverty did not interact in their relationship with lung cancer incidence (interaction $p = 0.50$).

Lung cancer mortality by rurality and persistent poverty

Overall, lung cancer mortality was 43.2 deaths/100,000 people/year (95% CI: 42.7–43.6), ranging from lowest in urban, non-persistent poverty counties (mean = 39.9 deaths/100,000 people/year, 95% CI: 39.3–40.6) to highest in rural, persistent poverty counties (mean = 52.1, 95% CI: 50.2–54.0). The ANOVA test showed significant differences in lung cancer mortality across county types (F-statistic = 78.43, $p < 0.001$). The post hoc Tukey test showed lung cancer mortality rates were lowest in urban, non-persistent poverty counties, and highest in rural, persistent poverty counties, compared to other county types (Fig. 1).

In multivariable analysis, lung cancer mortality was higher in rural counties compared to urban counties (estimate = 3.99, SE = 0.46, $p < 0.001$), as well as in persistent poverty counties compared to non-persistent poverty counties (estimate = 3.59, SE = 0.67, $p < 0.001$) (Table 2). Rurality and persistent poverty interacted in their relationship with lung cancer mortality (interaction $p < 0.001$). Specifically, for non-persistent poverty counties, rurality was associated with higher lung cancer mortality (estimate = 10.16, SE = 0.55, $p < 0.001$), and for persistent poverty counties, this relationship was even stronger (estimate = 18.81, SE = 1.66, $p < 0.001$) (Table 3).

Discussion

In this secondary analysis examining differences in smoking, lung cancer incidence, and lung cancer mortality by rurality and persistent poverty, we confirmed our hypothesis that these county-level characteristics interact to contribute to lung cancer disparities. Specifically, we found that the positive relationships between rurality and smoking and between rurality and lung cancer mortality were even more pronounced in persistent poverty counties than in other counties. Interestingly, rurality and persistent poverty did not interact significantly for lung cancer incidence. In addition, we found that the effect estimates for the relationships between persistent poverty and lung cancer risk, incidence and mortality were greater than the effect estimates for the relationships between rurality and each lung cancer risk, incidence and mortality.

Our study findings support the emerging literature examining the role of persistent poverty in cancer disparities [13, 18, 19, 24], and provide novel findings regarding the relationship between rurality and persistent poverty with lung cancer risk, incidence and mortality, but with a stronger magnitude for all the associations by persistent poverty status vs rurality. Importantly, our findings extend on prior studies examining lung cancer disparities across the cancer continuum by 1) examining rurality and persistent poverty simultaneously, and 2) by controlling for variables that may contribute to overall county-level disparities (e.g., health insurance, density of primary care providers, racial/ethnic composition). This is the first study to our knowledge that examines the interaction of

rurality and persistent poverty on lung cancer risk, incidence and mortality across the cancer continuum (i.e., risk, incidence, and mortality).

Based on our study findings, rurality and persistent poverty interact to contribute to the highest county-level smoking prevalence. Rurality was associated with higher smoking prevalence across all counties, although associations were stronger in persistent poverty counties. These findings are aligned with results from prior studies which consistently demonstrate rural and socioeconomic disparities in smoking prevalence. For example, rural populations have higher rates of smoking and are less likely to receive cessation treatment compared to their urban counterparts, which may due in part to limited access to primary health care and smoking cessation programs [25]. Poverty is also associated with an increased risk of smoking due to individual and community factors, such as exposure to tobacco products [26]. Indeed, tobacco companies often target advertising toward low-income communities with a high density of tobacco retailers [27]. Thus, our findings of the highest smoking prevalence in rural, persistent poverty communities may be attributable to the overlap of these and other adverse, multilevel factors.

Our results suggest that rural counties and persistent poverty counties have higher lung cancer incidence rates than their comparison counties. Perhaps surprisingly, there was not a significant interaction between rurality and persistent poverty in the relationship with lung cancer incidence. Rural lung cancer incidence disparities may be driven by individual health behaviors such as smoking, an aging population, poor access to health screening services [28], and lack of tobacco cessation treatment [27]. Patients living in communities with high poverty often face unique risks such as environmental exposures and safety (e.g., housing), and clinician biases related to lung cancer screening [29]. Future research is needed to investigate the factors contributing to lung cancer incidence disparities in counties that are rural or persistent poverty.

Rurality and persistent poverty interacted to contribute to the overall worst county-level lung cancer mortality rates. In rural communities, lung cancer mortality disparities may be driven by access to high quality cancer treatment [5, 28]. Lung cancer mortality disparities in communities with high levels of poverty may be driven by lack of supportive care, lack of education regarding cancer treatment, and importantly, financial concerns of receiving cancer treatment [30]. Persistent poverty communities have increased cancer mortality burden, perhaps due to the long-term impact of poverty on risk factors [13]. In addition, persistent poverty counties, particularly those in the South, have a higher percentage of marginalized racial and ethnic residents, who are exposed to systemic racism across the cancer continuum of care [18, 20]. Studies have suggested that individual, social, and environmental factors (e.g., socioeconomic status, rurality, and racism) are associated with lung cancer mortality [31]. Our study findings take the next step, demonstrating that social/geographic factors (i.e., rurality and persistent poverty) overlap to give rise to disparities across the lung cancer continuum.

Our study findings have both clinical and research implications. Clinicians should be aware that rurality and persistent poverty often overlap, and screen patients for these adverse social determinants of health accordingly. With this information, they could provide education on lung cancer screening and referrals to smoking cessation programs (e.g., in-person counselling, nicotine replacement therapy) as appropriate, especially targeted for patients from rural, persistent poverty communities [32, 33]. Researchers should evaluate and address the specific barriers to accessing these existing evidence-based interventions for residents of rural, persistent poverty counties. For example, research examining multilevel determinants of health is needed to examine the overlapping relationships of adverse individual, community, and environmental factors underpinning lung cancer disparities.

Strengths and limitations

Strengths of this study include the utilization of national data sources with nearly complete coverage of the U.S. population. Our analysis of smoking, lung cancer incidence, and lung cancer mortality by rurality and persistent poverty provides an important contribution to the existing literature on cancer disparities. Regarding limitations, findings from this county-level study cannot be generalized to individual-level risk, so future studies are needed to better understand the overlapping roles of rurality and persistent poverty on individuals' smoking, lung cancer incidence, and lung cancer mortality. Because this is a cross-sectional study, our findings cannot be used to examine causation; future research is needed to investigate causal relationships between social determinants (rurality, persistent poverty) and lung cancer risk, incidence and mortality. Further, residual confounding from excluded variables could impact the observed relationships; future studies should continue to examine other ecological factors that could contribute to lung cancer risk, incidence and mortality. Future multilevel studies should examine differences in individual, social, and environmental factors that impact health behaviors (social associations, smoking, cancer screening) between county types.

Conclusion

Rural, persistent poverty counties have significantly higher levels of smoking, lung cancer incidence, and lung cancer mortality compared to other county types. These findings suggest that adverse social determinants of rurality and persistent poverty overlap to contribute to disparities across the lung cancer control continuum. People living in counties with multiple adverse social determinants are at highest risk of poor lung cancer risk, incidence, and mortality, and clinical and community-level research and interventions are urgently needed to address lung cancer disparities experienced in rural, persistent poverty counties.

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Authors' contributions
VB: Conceptualization, Writing- Original draft preparation, Visualization, Investigation. KH: Methodology, Writing- Review & Editing. EA: Writing- Review & Editing. ST: Writing- Review & Editing. TL: Conceptualization, Writing- Review & Editing. JM: Supervision, Software, Data Curation, Methodology, Formal Analysis, Writing- Review & Editing.

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Data availability
This research results and conclusions are those of the authors and do not necessarily reflect the views of the National Cancer Institute or the University of Wisconsin Population Health Institute, of which the County Health Rankings and Roadmaps is an active program. Data on lung cancer incidence and mortality was obtained through the publicly-available NCI State Cancer Profiles, https://statecancerprofiles.cancer.gov/. Data on all other variables (e.g., smoking, access to primary care, health insurance status, racial/ethnic county composition) was obtained through the publicly-available County Health Rankings and Roadmaps dataset, https://www.countyhealthrankings.org/.

Declarations

Ethics approval and consent to participate
This secondary data analysis was deemed exempt by the Institutional Review Board.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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