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Is lung cancer mortality associated with the socioeconomic development of countries?

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Abstract:

BACKGROUND AND AIM: This study aims to quantify lung cancer mortality (LCM) in a developing country across different socioeconomic regions and explore the spatial relationships between these regions and their developmental levels.

METHODS: The study was conducted in Türkiye. Data on lung cancer deaths and population demographics from 2015 to 2019 were obtained from the Turkish Statistical Institute (TURKSTAT). The socioeconomic level of the subregions was determined using an index from the Ranking of Socioeconomic Development (RSED) study. Risk ratios were calculated relative to the subregion with the lowest rate. Both univariate and multivariate Moran's I methods were used to analyze spatial autocorrelation and to create a spatial cluster map of Türkiye.

RESULTS: From 2015 to 2019, the LCM rates in Türkiye were 49.70 per 100,000 for males and 7.81 per 100,000 for females. Spatial correlation analyses indicated significant correlations for both genders and overall (Moran's I: 0.699 for males, 0.306 for females, and 0.697 overall; $p<0.001$ for each). The standardized LCM rates were categorized into four groups based on quartile values. Both the quartile distribution and spatial autocorrelation analyses revealed that the highest LCM rates for both genders (58.75 per 100,000 for males and 10.99 per 100,000 for females) were predominantly found in the western part of the country. Conversely, the lowest LCM rates (21.29 per 100,000 for males and 5.72 per 100,000 for females) were mostly observed in the southeastern regions. Additionally, a positive linear relationship was found between the socioeconomic development index scores of the regions and their LCM rates (Moran's I: 0.536, 0.315, and 0.533, respectively; $p<0.001$ for each).

CONCLUSIONS: Higher rates of LCM were significantly associated with densely populated, industrialized, and urban areas. These findings may assist policymakers in designing targeted interventions to effectively reduce the lung cancer burden in areas with the greatest need.

Keywords:

Lung cancer mortality, Moran's I, socioeconomic development, spatial analysis

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Introduction

Lung cancer imposes a significant global health burden. Over the past few decades, it has been the leading cause of cancer-related deaths worldwide, ranking first among men and second among women.[1] It is associated with a poor prognosis, with a 5-year relative survival rate below 19% for men and less than 27% for women in most countries.[2]

The primary preventable risk factors for lung cancer include lifestyle habits such as smoking, as well as environmental and occupational exposures. The influence of these factors on lung cancer risk varies by geographic location, gender, race, genetic predispositions, and their interactive effects. Research suggests that socioeconomic factors play a crucial role in the prevalence of these risk factors.[3,4]

The incidence of lung cancer differs significantly between countries and even within regions of the same country. In 2019, incidence rates in low-income countries were recorded at 4.5 per 100,000 for males and 2.0 per 100,000 for females. In contrast, high-income countries reported rates of 70.0 per 100,000 for males and 44.0 per 100,000 for females.[5] The incidence rate of lung cancer in high-income countries is approximately 20 times higher than in low-income countries.[4] The Global Burden of Disease study demonstrated a nonlinear regression relationship between the Disability Adjusted Life Years (DALY) for lung cancer and the sociodemographic index of countries, underscoring the importance of this relationship in understanding the disease's epidemiology.[6–8]

According to the Global Cancer Observatory (GLOBOCAN) 2019 report, the standardized incidence rates of lung cancer in Türkiye were 59.2 per 100,000 for males and 12.9 per 100,000 for females. The mortality rates were similarly high, recorded at 60.3 per 100,000 for males and 12.6 per 100,000 for females.[5] Türkiye is one of the countries with high lung cancer mortality rates (LCM) in men. Although classified by the World Bank as a middle-income to high--income country, Türkiye encompasses regions with varying socioeconomic characteristics.[9] Highlighting the correlation between global lung cancer mortality and socioeconomic status is important, especially in a country with different levels of regional development.

The use of Geographic Information Systems and spatial analysis to explore the spatial distribution of diseases is growing.[10,11] Specifically, studies that demonstrate spatial patterns using a Local Indicator of Spatial Association (LISA) are essential in epidemiological research on lung cancer.[12] The objective of this study is to calculate LCM in a developing country, differentiating between various socioeconomic regions, and to examine the spatial relationships between these regions and their development levels.

Materials and Methods

Study area and population

We conducted a spatial autocorrelation analysis in Türkiye, which is situated between 36–42° north latitude and 26–45° east longitude. The country spans an area of 783,562 square kilometers, with 755,688 square kilometers located in Asia and 23,764 square kilometers in Europe.[13] As of 2019, Türkiye's population was 85,279,553.[14]

Mortality data

Data on the annual number of lung cancer deaths and population figures for the years 2015–2019 were sourced from the Turkish Statistical Institute (TURKSTAT). TURKSTAT records and publishes national death data annually, utilizing the International Classification of Diseases, Tenth Revision (ICD-10) as the classification system for mortality.[15] Lung cancer is classified as C32-C34. Data on lung cancer deaths and population were grouped into 5-year age brackets, ranging from 0 to 75 years and older, and were further categorized by sex and geographic location.[14]

Regions of Türkiye

Türkiye is divided into 26 sub-regions (SRs) as per the Nomenclature of Territorial Units for Statistics (NUTS)-2, defined by EUROSTAT. The study analyzed data from each SR, including Istanbul, Tekirdag, Balikesir, Izmir, Aydin, Manisa, Bursa, Kocaeli, Ankara, Konya, Antalya, Adana, Hatay, Kırıkkale, Kayseri, Zonguldak, Kastamonu, Samsun, Trabzon, Erzurum, Agri, Malatya, Van, Gaziantep, Sanliurfa, and Mardin, for geographic assessment. The map utilized was procured from the General Directorate of Cartography in Türkiye.[16] Geographic data were visualized using the Quantum Geographic Information System (QGIS) software, version 3.28.

Socioeconomic level of subregions

To evaluate the socioeconomic level of each subregion, we referenced an index from the Ranking of Socio-economic Development (RSED) study. This study, conducted to assess the socioeconomic development rankings of SRs in

Türkiye in 2017,[9] encompassed various criteria including demographics, employment, education, health, competitiveness and innovation, finance, accessibility, and quality of life. Each SR was scored based on these criteria. In these rankings, the Istanbul SR scored the highest with an index of 4.051, whereas the Van SR recorded the lowest at -1.506.[9]

Statistical Analyses

The study data was organized in an Excel spreadsheet. LCM rates by age group and gender were calculated annually at the regional level, using population and cancer incidence data for each SR. LCM was expressed as a rate per 100,000 individuals.

Age-adjusted mortality rates were computed using the direct standardization method, taking the world standard population as the benchmark.[17] The standard error and the 95% confidence interval (CI) were determined using the Poisson distribution model.

For each gender and the overall population, the differences in lung cancer mortality risk across various years were assessed using rate ratios (RR) with 95% CI. Specifically, these differences were calculated by comparing the risk ratios of standardized LCM in different years, with calculations anchored to the standardized LCM rate in 2015. The annual RRs and 95% CIs were calculated to assess yearly changes in mortality risk relative to this baseline.

SRs were categorized into four groups based on the quartile distribution of standardized lung cancer mortality rates. For males, the Quartile 1 (Q1), median (Q2), and Quartile 3 (Q3) values were recorded at 39.01, 45.14, and 54.46 per 100,000, respectively. For females, these values were 6.00, 6.6, and 7.82 per 100,000, respectively. The overall population rates were 21.69, 24.36, and 28.6 per 100,000, respectively. The RRs for mortality in other locations and their 95% CIs were calculated in comparison to the lowest 25% of standardized lung cancer death rates.[18] The outcomes, expressed in 95% CIs, indicate whether a rate ratio is equivalent to (RR=1), higher than (RR>1), or lower than (RR<1) the reference rate.

A map delineating subregions, based on NUTS-2 divisions, was created using QGIS software and subsequently analyzed with GeoDa software (version 1.20.0.22, Spatial Analysis Laboratory, University of Illinois at Urbana-Champaign, EUA). The global Moran index was employed to assess the spatial autocorrelation of standardized LCM rates. Spatial clusters were evaluated using the Local Indicators of Spatial Association (LISA), with distance serving as the basis for the weight matrix. The Moran's I value ranges from +1 to -1. A Moran's I value of 0 indicates a random pattern. Positive values suggest a positive spatial correlation, indicating strong aggregation between them. Conversely, negative values suggest a negative spatial correlation between regions.[19] Initially, the logarithm of the standardized LCM rates was calculated using the natural log (ln) base and a spatial autocorrelation analysis was performed using Local Moran's I. The analysis revealed that LCM rates were spatially correlated among males, females, and the total group (Moran's I = 0.699, $p<0.001$; Moran's I = 0.306, $p<0.001$; Moran's I = 0.697, $p<0.001$, respectively). According to the LISA significance levels, regions were classified in the spatial autocorrelation analysis as follows: high-high if the region is defined by NUTS-2 with a high frequency of the variable and is surrounded by high-frequency NUTS-2 regions; low-low if the region of NUTS-2 has a low frequency of the variable and is surrounded by low-frequency NUTS-2 regions; high-low if a high-frequency NUTS-2 region is surrounded by low-frequency regions; and low-high if a low-frequency NUTS-2 region is surrounded by high-frequency NUTS-2 regions.

Two methods were used to correlate RSED scores with standardized LCM rates.

First, the relationship between the standardized LCM rates and the RSED scores was modeled using ordinary least squares (OLS) regression analysis. Second, the LISA analysis was performed by adapting Moran's I formula to measure the spatial interaction of the LCM rate with the socioeconomic index and to identify clustering for each spatial unit. LISA cluster maps are categorized into four types: High-High, High-Low, Low-Low, and Low-High.[20]

Ethical approval

The data for this study were provided by the Turkish Statistical Institute (TURKSTAT) following a formal request. These data can be freely used by researchers for further analysis. No artificial intelligence or assisted technologies were used in this study. The TURKSTAT data were collected in compliance with both national and international ethical standards. As this was a register-based study that did not include individual data, neither informed consent nor ethical approval was required. The study was conducted in accordance with the Declaration of Helsinki.

Table 1: Lung cancer death numbers and rates by sex during 2015–2019 (Türkiye)

	Time period					
	2015	2016	2017	2018	2019	2015–2019
Male						
Death number	19.289	19.883	19.929	19.919	19.469	98.489
Crude rate/10^5	48.82	49.65	49.16	48.42	46.66	48.53
Standardized rate/10^5	52.02	52.07	50.58	48.73	45.70	49.70
RR (95% CI)	1	1.00 (0.98–1.02)	1.03 (1.01–1.05)	1.07 (1.05–1.09)	1.14 (1.16–1.12)	
Female						
Death number	3.501	3.631	3.582	3.859	3.650	18.223
Crude rate/10^5	8.92	9.13	8.89	9.44	8.81	9.04
Standardized rate/10^5	7.98	8.05	7.70	8.04	7.32	7.81
RR (95% CI)	1	0.99 (0.95–1.04)	1.04 (0.99–1.04)	0.99 (0.95–1.04)	1.09 (1.04–1.14)	
Total						
Death number	22.790	23.514	23.511	23.778	23.119	116.712
Crude rate/10^5	28.94	29.46	29.09	29.00	27.80	28.85
Standardized rate/10^5	28.29	28.32	27.45	26.78	24.97	27.10
RR (95% CI)	1	1.00 (0.98–1.02)	1.03 (1.01–1.05)	1.06 (1.04–1.08)	1.13 (1.11–1.15)	

RR: Risk ratio, CI: Confidence interval

Results

Mortality

Between 2015 and 2019, the total number of lung cancer deaths in Türkiye was 98,489 in men and 18,223 in women. The average annual number of lung cancer deaths over this five-year period was 19,698 for men and 3,645 for women. The average annual crude LCM rate was 48.53 per 100,000 in males and 9.04 per 100,000 in females. The standardized LCM rate was 49.70 per 100,000 (95% CI: 49.76–49.65) in males and 7.81 (95% CI: 7.83–7.85) in females. The mortality rate was significantly higher in males than in females, being 6.36 times greater (95% CI: 3.91 to 10.37; $p<0.001$).

In the study, the age-standardized LCM rate for individuals aged 20 years and older was 75.70 per 100,000 in males (95% CI: 58.64–92.75), 11.93 per 100,000 (95% CI: 5.16–18.71) in females, and an overall rate of 41.35 per 100,000 (95% CI: 28.75–53.96). The standardized LCM rate exhibited a decrease solely in 2019 compared to 2015. Table 1 displays both crude and standardized rates of lung cancer mortality categorized by sex and years, while Table 2 illustrates the distribution of lung cancer mortality by subregion.

The standardized LCM rates were stratified into four groups based on quartile values. RRs were computed relative to the SR with the lowest rate. Subregions in the first quartile (Q1), typically situated in the southeastern part of the country, demonstrated the lowest LCM rates, whereas those in the Q4, predominantly in the western part of the country, exhibited the highest LCM rates [Fig. 1a-c]. We observed a social gradient in mortality RRs, with positive RRs indicating higher mortality rates in groups with elevated socioeconomic levels, observed in both males and females.

The relationship between the RSED scores and standardized LCM of subregions was investigated using OLS regression analysis. A linear positive association was found between RSED scores and standardized LCM of subregions (Table 3).

Spatial Analysis

An analysis of spatial autocorrelation for standardized LCM rates among male, female, and overall populations between 2015 and 2019 revealed positive spatial autocorrelation. The Moran's I index values for male, female, and overall populations were significant (0.699, 0.306, and 0.697, respectively; $p<0.001$). In males, regions such as Istanbul, Tekirdag, Balikesir, Izmir, Manisa, and Bursa demonstrated notably higher LCM rates, whereas Hatay, Malatya, Van, Gaziantep, and Sanliurfa exhibited lower rates.

For females, Tekirdag and Balikesir were regions with significantly higher LCM, while Gaziantep reported the lowest. The spatial distribution of regions with significantly higher and lower LCM rates was broadly similar to that observed in males. Figure 2a-c presents a LISA cluster map illustrating the spatial clustering of standardized LCM rates.

Table 2: Distribution of lung cancer deaths by subregions during 2015–2019 (Türkiye)

	Subregion	Male			Female			Total		
		Death number	Crude rate/10^5	Standardized rate/10^5	Death number	Crude rate/10^5	Standardized rate/10^5	Death number	Crude rate/10^5	Standardized rate/10^5
1	Istanbul	16.729	44.44	54.97	3.978	10.63	10.61	20.707	27.58	30.53
2	Tekirdag	4.006	88.80	74.00	563	13.08	9.10	4.569	51.83	39.49
3	Balikesir	4.316	99.12	63.85	601	13.86	7.75	4.917	56.59	34.06
4	Izmir	7.926	74.47	61.93	1.615	15.07	10.52	9.541	44.67	33.99
5	Aydin	4.745	62.14	47.67	723	9.54	6.30	5.468	35.94	25.58
6	Manisa	5.182	67.68	54.29	678	8.82	5.91	5.860	38.19	28.23
7	Bursa	6.768	67.09	61.39	1.055	10.52	8.01	7.823	38.89	32.61
8	Kocaeli	5.369	56.21	55.31	860	9.12	7.71	6.229	32.81	29.96
9	Ankara	5.832	43.20	44.65	1.270	9.27	7.86	7.102	26.11	24.43
10	Konya	2.828	46.86	45.44	472	7.72	6.39	3.300	27.16	24.29
11	Antalya	3.353	43.23	39.83	615	8.03	6.36	3.969	25.75	22.12
12	Adana	4.107	41.06	41.72	820	8.18	7.21	4.927	24.60	23.22
13	Hatay	2.118	25.95	29.43	443	5.53	5.37	2.561	15.83	16.79
14	Kirikkale	1.937	49.61	44.61	367	9.34	6.64	2.261	28.86	23.48
15	Kayseri	2.817	46.42	41.62	534	8.81	6.69	3.351	27.64	23.04
16	Zonguldak	1.739	67.60	49.49	261	10.01	6.25	2.000	38.61	26.08
17	Kastamonu	1.437	73.85	43.21	246	12.57	6.04	1.684	43.15	23.49
18	Samsun	4.159	60.32	44.83	673	9.61	6.08	4.832	34.76	24.07
19	Trabzon	4.601	69.63	49.85	618	9.29	5.28	5.219	39.36	25.53
20	Erzurum	1.233	45.61	46.05	266	9.93	7.81	1.499	27.85	25.51
21	Agri	938	32.25	46.51	192	7.10	7.96	1.130	20.13	26.01
22	Malatya	1.632	37.52	36.55	356	8.27	6.59	1.988	22.97	20.39
23	Van	895	16.22	33.66	243	4.68	7.64	1.138	10.62	19.49
24	Gaziantep	1.579	22.71	33.43	270	3.96	4.51	1.849	13.43	17.80
25	Sanliurfa	1.482	15.94	32.73	302	3.30	5.27	1.784	9.67	17.49
26	Mardin	803	14.12	28.97	196	3.58	5.19	999	8.95	15.67

Table 3: Relationship between standardized lung cancer mortality rate and RSED using ordinary least squares regression model

	Coefficient	SE	t-statistic	Probability
Male				
Constant	3.773	0.041	90.181	<0.001
RSED	0.102	0.032	3.172	0.00411
R^2=0.295; F=10.0629; p=0.0041				
Female				
Constant	1.884	0.0359	52.432	<0.001
RSED	0.096	0.0279	3.440	0.00214
R^2=0.330; F=11.835; p=0.0021				
Total				
Constant	3.162	0.039	80.004	<0.001
RSED	0.102	0.031	3.319	0.0029
R^2=0.3146; F=11.014; p=0.0029				

RSED: Ranking of Socio-economic Development, SE: Standard error

The bilateral correlation between LCM rates in males and the RSED index identified high-high SRs in Tekirdag, Manisa, and Kocaeli, and low-low SRs in Malatya, Van, Sanliurfa, and Gaziantep. In females, high-high SRs included Tekirdag and Kocaeli, with low-low SRs in Malatya, Sanliurfa, and Gaziantep; Manisa showed low-high, and Erzurum, Agri, and Van exhibited high-low correlations. The study suggests a social gradient in mortality rates for both genders.

The LISA cluster map created to demonstrate the spatial clustering of standardized LCM rates using the RSED index is displayed in Figure 3a-c.

Regions such as Istanbul, West Marmara, and East Marmara exhibited high positive correlations, whereas the regions in Southeast Anatolia showed a low correlation between both variables (male: 0.499; p<0.001, female: 0.419; p<0.001).

Discussion

The investigation of geographic mortality patterns offers insights into population health status and informs health policy. With advances in Bayesian modeling and geographic information systems, more studies now ac-

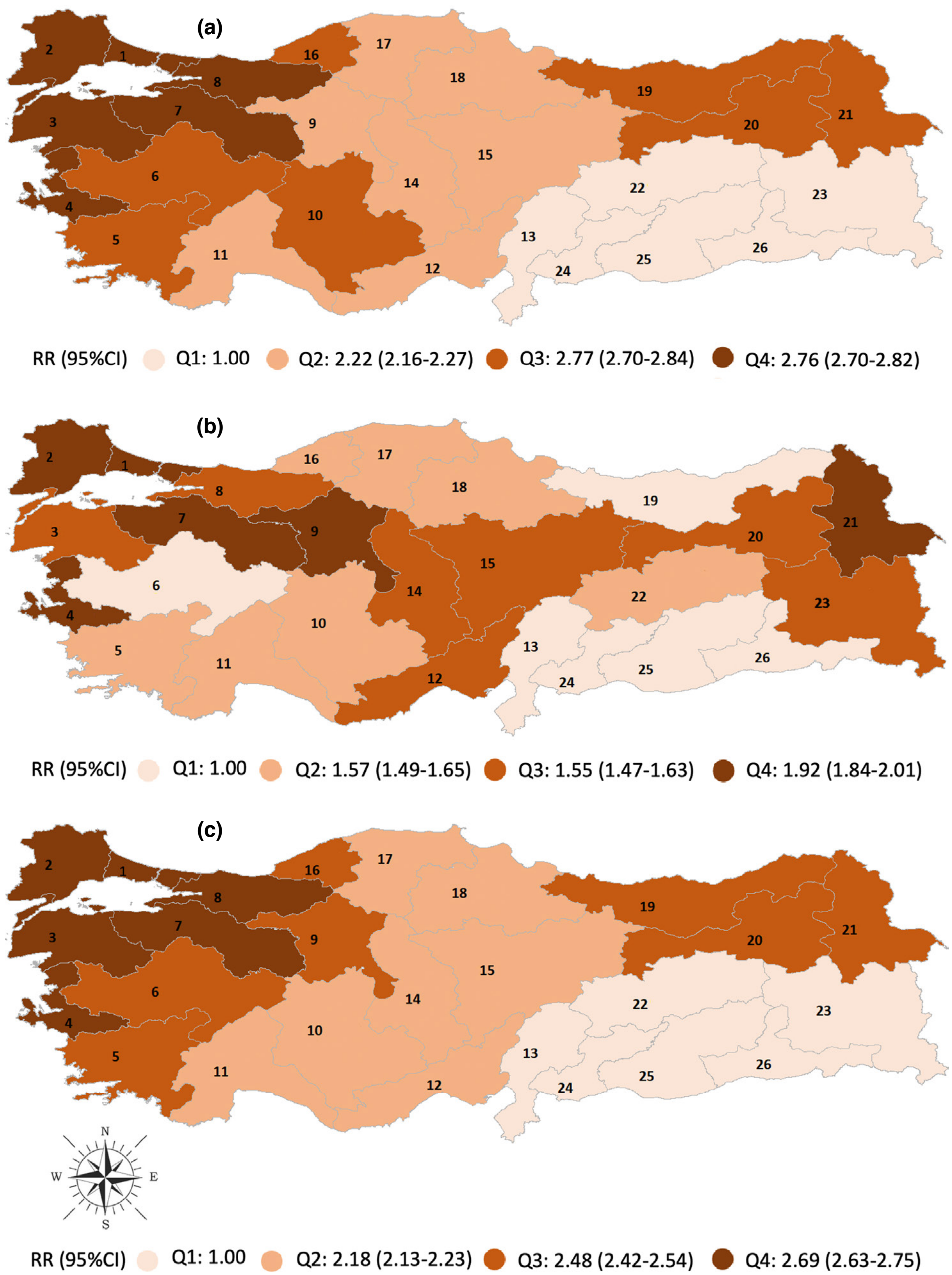

Figure 1: (a-c) Risk ratio and 95% confidence interval by quartiles of standardized lung cancer mortality rate in subregions
a: Male, b: Female, c: Total. RR: Risk ratio

knowledge geographic regions as significant determinants of health outcomes.[10,21–23] These tools not only reveal detailed distributions of mortality but also facilitate the exploration of potential associations with various independent variables.[24,25] Most studies of LCM in the literature focus on the geographic aspects of the physical environment, such as radon and air pollution, while fewer examine social determinants. These studies are primarily conducted in China and several Western countries.[10,11,24] In the current study, a spatial analysis of the relationship between socioeconomic status and standardized LCM rates in Türkiye, a developing country, was conducted. It revealed significant differences across both genders and demonstrated a distinct east-west gradient in the data.

The LCM rate was reported as 37.4 per 100,000 in males and 15.0 per 100,000 in females worldwide.[26] In this study, the LCM rate in Türkiye between 2015 and 2019 was 49.70 per 100,000 in males and 7.81 per 100,000 in fe-

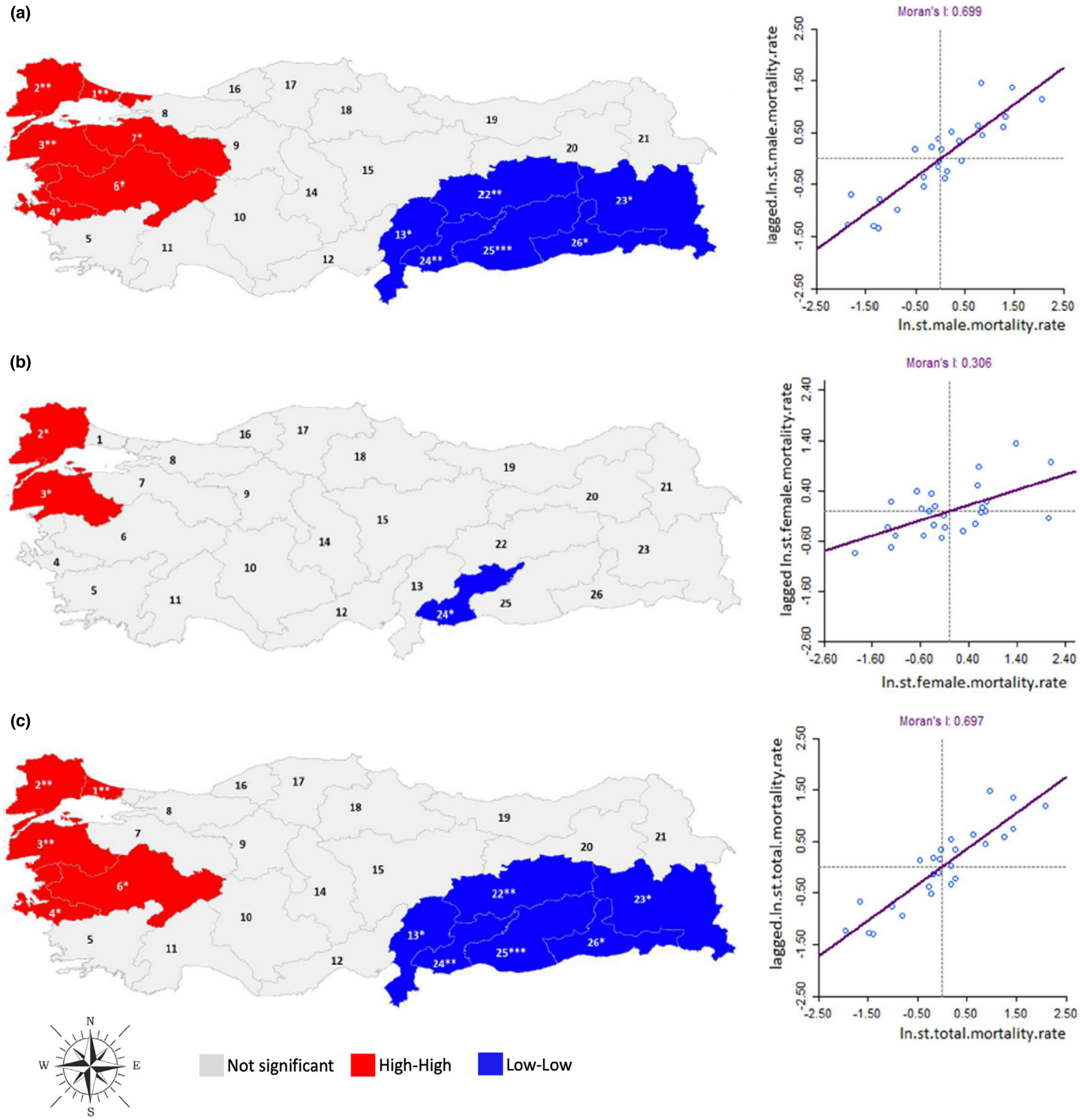

Figure 2: (a-c) Cluster map and Moran's scatter plot of linear standardized lung cancer mortality by NUTS-2 regions in Türkiye

*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$. a: Male, b: Female, c: Total

males. Compared to the global average, the rate is higher for males and lower for females in Türkiye. For males, the LCM rate in Türkiye exceeds that of Brazil, Iran, Kazakhstan, Egypt, and India, where the rates are 20.4, 14.4, 33.1, 8.2, and 8.8 per 100,000 population, respectively. However, it is lower than in Germany, the United States, Bulgaria, Hungary, Greece, and China, which have rates of 83.6, 70.4, 107.8, 119.6, 134.7, and 72.2 per 100,000, respectively. For females, the LCM rate in Türkiye is lower than in most of these countries (for Brazil, Kazakhstan, Germany, the United States, Bulgaria, Hungary, Greece, and China: 13.9, 8.1, 43.8, 55.6, 27.4, 68.3, 35.2, and 33.5 per 100,000,

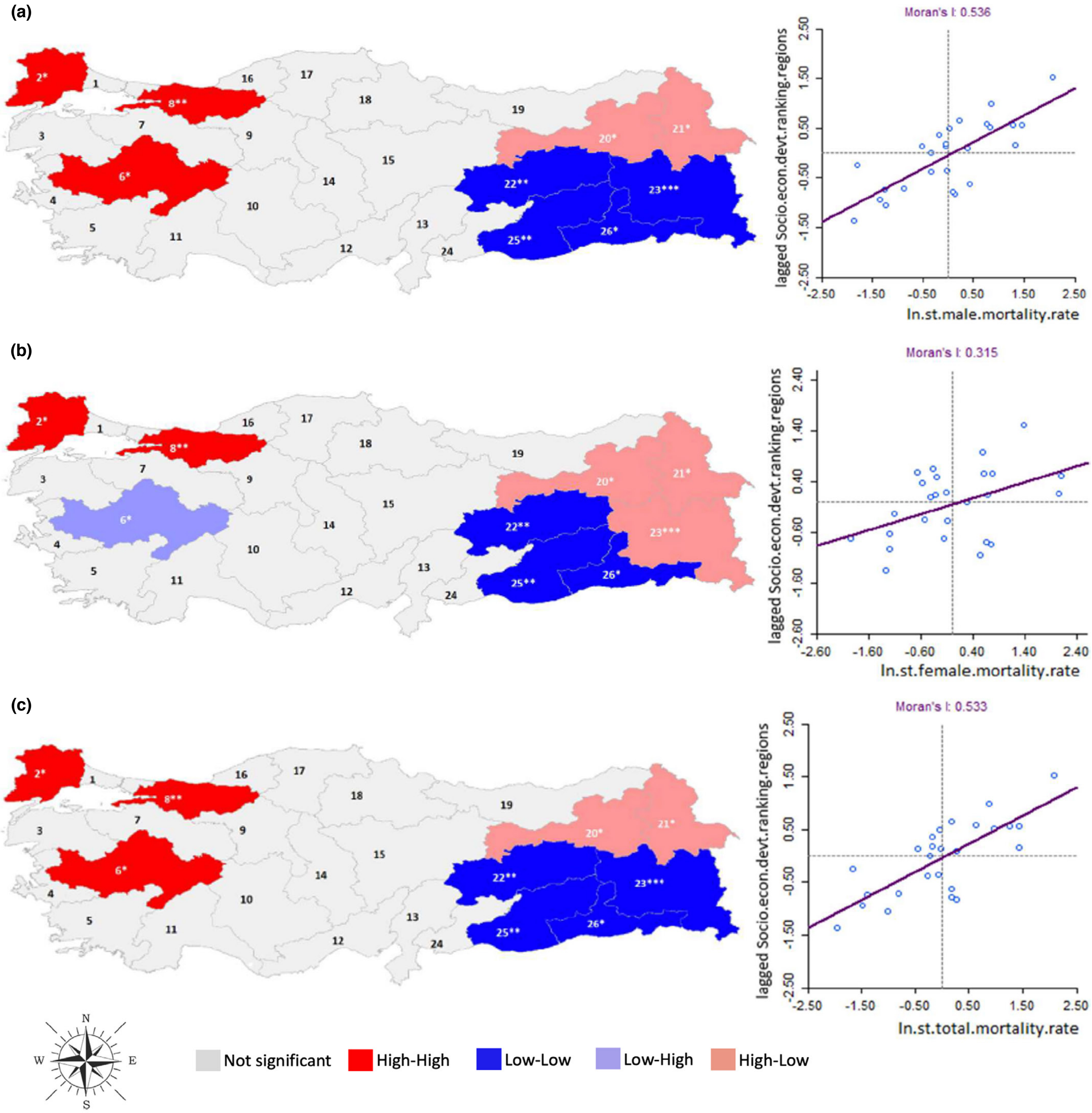

Figure 3: (a-c) Cluster map and Moran's scatter plot showing regional ranking of socioeconomic development of NUTS-2 regions in Türkiye, based on linear standardized lung cancer mortality rates (2015-2019)

*: p<0.05, **: p<0.01, ***: p<0.001. a: Male, b: Female, c: Total

respectively). However, it is higher than in Iran, Egypt, and India, where the rates are 6.7, 3.9, and 3.9 per 100,000, respectively.[5] These differences in LCM rates may be attributed to factors such as cigarette consumption, industrialization levels, socioeconomic status, and the efficacy of health system registration and service delivery.

In summary, LCM rates are lower in some countries, such as those in South America, and certain Asian and African nations, compared to Türkiye, yet higher in Eastern and Western Europe and China. Explaining regional differences in LCM rates is challenging; however, factors such as higher levels of industrialization and/or less restrictive smoking regulations may play a role. Additionally, the lower LCM rate in females in Türkiye compared to other countries could be attributed to women entering the workforce later than in other countries.

This study is one of the few local studies that illustrate the risk associated with the socioeconomic index for LCM across different spatial regions.[10,11,25,27] The disparities in LCM rates across regions in Türkiye were unveiled using two methods. The study provided quantitative evidence of the spatial distribution of lung cancer by calculating the RR and 95% CI through comparative risk assessment. Moreover, geospatial statistical modeling was employed. The findings from both analyses were consistent with each other. The spatial disparity in LCM was more pronounced in males than in females, with Moran's I values of 0.699 and 0.306 for males and females, respectively. We demonstrated that LCM distribution in Türkiye is uneven. Regions with low LCM rates in males were concentrated in Southeast Türkiye, while those with high rates (6 regions) were predominantly in Eastern and Western Marmara, including Istanbul. This distribution aligns with global industrialization patterns.[26]

Türkiye is a country that has not yet completed its demographic transition and faces significant socioeconomic inequalities. LCM rates are particularly high in the western regions, where the population is older and transitioning from an agrarian society to industrialization. The LCM rate is lower in females than in males, and a less pronounced spatial pattern was observed in females.

The correlation between the RSED and LCM rates was analyzed using both OLS regression analysis and the LISA mapping. The RSED is a composite index that gauges the socioeconomic development level of provinces and identifies regions in need of priority development. A stronger positive correlation was found between the RSED and LCM rates in males than in females.

Previous studies have primarily linked LCM to smoking habits. In Türkiye, the prevalence of smoking is notably high, with significant differences between sexes.[28] The prevalence of smoking among adults aged 15 years and older in Türkiye in 2014 was 41.8% for men and 13.1% for women, with about one-third of the population being smokers. These rates remained stable in 2019, recorded at 41.3% for men and 14.9% for women.[29] The current LCM rate is a result of smoking prevalence from at least 20 years ago, which is now more accurately reflected among individuals over 35 years of age. Among males, the percentages of those who smoke and have quit smoking are 35.8%, 71.3%, 77.5%, 73.5%, and 66.9% across the 35–44, 45–54, 55–64, 65–74, and 75+ age groups, respectively. For females, these percentages are 31.0%, 27.6%, 24.1%, 15.8%, and 9.2%, respectively.[29]

The prevalence of smoking among women in Türkiye has increased sharply in recent years, rising by approximately 40% between 1997 and 2019.[30] However, this increase is not reflected in the timeframe of the current study but it is expected to impact the rate of lung cancer in women in future years. Türkiye is a country that is undergoing a transformation from its traditional culture to a global popular culture, largely influenced by mass media. Research has shown a positive association between education and smoking among women in Türkiye.[30] This has significantly altered the traditional role of women in Türkiye. According to the Organisation for Economic Co-operation and Development (OECD) data, female labor force participation increased from 22.8% in 2005 to 31.7% in 2021.[31] The prevalence of smoking among women in Türkiye has risen following changes in labor conditions.

In terms of smoking prevalence, there is not much difference between the eastern and western provinces of Türkiye. A nationwide study found that the percentage of regular smokers ranges from 24.3% to 26.9% in regions with high LCM and from 22.7% to 24.7% in regions with low LCM.[32] This suggests that smoking may not be the primary factor influencing the differences in LCM across regions in Türkiye. Therefore, factors other than smoking should be considered when explaining the geographic disparities in LCM in men, as indicated by the spatial analysis.

The population in regions with high LCM among men represents more than one-third (36.9%) of the total population. The two SRs with high rates among women are also located in the western part of the country; however, these SRs account for only 4.9% of the total population. While the population density in regions with high LCM rates is 280.25 people per km^2, it drops to 86.75 people per km^2 in regions with low mortality rates (compared to the Turkish average of 109 residents/km^2). In regions with high LCM, 12.4% of the total population are men over 65 years of age, versus 5.8% in regions with low mortality. The proportion of the population in settlements with fewer than 20,000 residents is 3.5% in high LCM regions and 9.8% in low mortality regions. Furthermore, 65.3% of workplaces with more than 250 employees are located in high LCM regions, compared to only 12.6% in regions with low mortality.[14] Thus, LCM was found to be significantly higher in more populous, industrialized, and urban areas than in the country as a whole. High rates in the current study were confirmed in regions with better socioeconomic and health services. Among males, LCM is higher in more developed regions and at higher socioeconomic levels. The total number of physicians per 100,000 population was 78 in high LCM regions, compared to 55 in low LCM regions.[14]

In the United States, LCM was higher during periods of economic growth in regions with higher socioeconomic status.[11,33] In China, characterized by industrialization and varying socioeconomic levels, higher cancer rates were observed in more affluent areas compared to traditional agricultural societies. Similarly, LCM rates in Brazil were found to be higher in economically affluent regions. The results of this study are consistent with findings from China and Brazil, where high LCM rates correlate with socioeconomically developed regions of these countries. The trend of LCM in developing countries is expected to eventually mirror that of the United States and Western countries, which have completed their industrialization and demographic transformations.[27,34]

This study has some limitations. It carries the inherent risk associated with ecological studies. Cancer incidence data in Türkiye are not directly accessible, and cancer mortality data were obtained from TURKSTAT following data improvement efforts. However, cancer incidence data could provide more meaningful insights for risk assessment.[35]

Nonetheless, the study sheds light on future research opportunities using spatial information technologies to identify risk factors responsible for LCM. Epidemiological studies employing small-area spatial analysis will contribute to the understanding of associated risk factors. This study can serve as a guide for countries that have not yet completed their demographic transitions or economic development processes. A key strength of this study is its integration of socioeconomic development status and lung cancer mortality in Türkiye, utilizing spatial interpolation estimation and risk assessment.

Conclusion

LCM was found to be higher in regions with greater urbanization, population density, industrialization, socioeconomic status, and better healthcare infrastructure. Since there are no regional differences in the prevalence of smoking in Türkiye, these results suggest that industrial development is a notable factor. The environmental impact of industrial densification in specific regions can be severe. We believe these findings can guide authorities and policy makers in prioritizing industrial development activities. It can also be inferred that regional variations in LCM are influenced by differences in medical care, although further research is needed in this area.

Authorship Contributions

Concept – S.M., M.M., G.A.; Design – S.M.; Supervision – M.M.; Data collection &/or processing – G.A., O.H.A.; Analysis and/or interpretation – S.M.; Literature search – S.M., G.A.; Writing – S.M., G.A.; Critical review – S.M., M.M., G.A.

Conflicts of Interest

There are no conflicts of interest.

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