Test file: Spatial-Temporal Patterns of Tuberculosis Incidence in Urban Slums: A Geospatial Analysis

Authors: Rongqiang Zhang[1], Xiantao Zeng[2], Shengli Wu[3]*

Affiliations:

[1] Shaanxi University of Chinese Medicine, Xianyang 712046, China

[2] Zhongnan Hospital of Wuhan University, Wuhan 430071, China

[3] LifeCenter Northwest, Seattle 98101, USA

***Corresponding Author:**

Shengli Wu, Email: victorywu2000@163.com

Abstract

This geospatial analysis examines tuberculosis incidence patterns in urban slums across five major cities. Using spatial scan statistics and geographic information systems, we identified significant disease clusters associated with population density and healthcare access. The findings inform targeted TB control strategies in high-risk urban areas.

Keywords: Tuberculosis; Spatial Analysis; Urban Slums; Infectious Disease Epidemiology; Disease Clusters; Public Health Surveillance

1. Introduction

Tuberculosis (TB) remains a major global health challenge, with an estimated 10 million new cases and 1.5 million deaths annually [1]. Urban slums represent particularly vulnerable settings for TB transmission due to overcrowding, poor ventilation, and limited access to healthcare services [2]. The complex interplay of social, environmental, and demographic factors in these settings creates heterogeneous patterns of disease distribution that require sophisticated analytical approaches to understand and address.

Spatial epidemiology provides powerful tools for identifying disease hotspots and understanding the underlying determinants of disease distribution [3]. Previous studies have demonstrated the utility of geographic information systems (GIS) and spatial scan statistics in identifying TB clusters in various settings [4,5]. However, few studies have specifically focused on the dynamic spatial-temporal patterns of TB incidence in urban slums across multiple cities, limiting our ability to develop targeted interventions for these high-risk populations.

This study aims to characterize the spatial-temporal patterns of TB incidence in urban slums across five major cities in Asia and Africa, identify significant disease clusters, and examine the environmental and socioeconomic factors associated with these clusters. The findings will contribute to evidence-based TB control strategies in urban slum settings.

2. Methods

2.1 Study Setting and Design

We conducted a retrospective spatial-temporal analysis of TB cases reported from 2018 to 2023 in urban slums across five cities: Mumbai (India), Dhaka (Bangladesh), Nairobi (Kenya), Lagos (Nigeria), and Manila (Philippines). These cities were selected based on their high TB burden and well-defined slum populations.

2.2 Data Sources and Case Definition

TB case data were obtained from national TB control programs, complemented by active case

finding initiatives in slum areas. A confirmed TB case was defined according to WHO guidelines [6]. Population data were derived from census records and satellite-based population estimates. Environmental and socioeconomic data were collected from municipal records and household surveys.

2.3 Spatial Analysis

We used SaTScan software to perform spatial scan statistics for detecting TB clusters [7]. The analysis employed a discrete Poisson model to identify areas with higher than expected TB incidence rates. Statistical significance was assessed using 999 Monte Carlo simulations. GIS mapping was performed using ArcGIS 10.8 to visualize disease patterns and cluster locations.

2.4 Risk Factor Analysis

Multilevel Poisson regression models were used to examine associations between TB incidence and potential risk factors, including population density, housing quality, access to healthcare facilities, and socioeconomic indicators. Models were adjusted for spatial autocorrelation using conditional autoregressive priors.

3. Results

3.1 TB Incidence Patterns

A total of 25,478 confirmed TB cases were included in the analysis. Annual TB incidence rates in the studied slums ranged from 312 to 587 per 100,000 population, substantially higher than national averages. All cities showed significant spatial heterogeneity in case distribution, with clear hotspots emerging in specific slum areas.

3.2 Spatial-Temporal Clusters

Spatial scan statistics identified 17 significant TB clusters across the five cities ($p < 0.001$). The most likely cluster was located in Mumbai, with a relative risk of 3.45 (95% CI: 2.98-4.01). Temporal analysis revealed persistent clustering in certain areas, while other clusters showed seasonal variation, with peak incidence during monsoon seasons.

3.3 Associated Risk Factors

Multilevel analysis identified several factors significantly associated with TB clustering. Population density (RR: 1.32, 95% CI: 1.18-1.47), inadequate ventilation (RR: 1.45, 95% CI: 1.29-1.63), and distance to nearest TB diagnostic center (RR: 1.28, 95% CI: 1.14-1.43) were the strongest predictors of cluster membership.

4. Discussion

4.1 Key Findings

This multi-city spatial analysis reveals distinct patterns of TB transmission in urban slums, with persistent disease clusters linked to specific environmental and healthcare access factors. The identification of these high-risk areas provides valuable insights for targeted TB control interventions.

4.2 Public Health Implications

The findings support a precision public health approach to TB control in urban settings. Resources should be prioritized for identified hotspot areas, with interventions tailored to local risk factors. Mobile diagnostic services and community-based care models could effectively address access barriers in these settings.

4.3 Limitations

The study limitations include potential underreporting of TB cases, particularly in informal settlements, and the ecological nature of the risk factor analysis. Future studies should incorporate molecular epidemiology to better understand transmission dynamics within identified clusters.

5. Conclusion

This geospatial analysis demonstrates the utility of spatial epidemiology in understanding TB transmission patterns in urban slums. The identified clusters and associated risk factors provide evidence for targeted interventions to reduce TB burden in these high-risk settings. Integration of spatial analysis into routine TB surveillance could enhance control program effectiveness.

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