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Short Communication

Spatial risk of tuberculosis mortality and social vulnerability in Northeast Brazil

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Abstract

Introduction: Tuberculosis (TB) is the most common infectious disease in the world. We aimed to analyze the spatial risk of tuberculosis mortality and to verify associations in high-risk areas with social vulnerability. **Methods:** This was an ecological study. The scan statistic was used to detect areas at risk, and the Bivariate Moran Index was used to verify relationships between variables. **Results:** High-risk areas of tuberculosis mortality were statistically significantly associated with domain 2 of the Social Vulnerability Index (I=0.010; p=0.001). **Conclusions:** This study provides evidence regarding areas with high risk and that vulnerability is a determinant of TB mortality.

Keywords: Tuberculosis. Social vulnerability. Spatial analysis.

Tuberculosis (TB) is one of the oldest infectious diseases and remains a serious public health problem worldwide, despite all efforts to control the disease. In 2015, 10.4 million people contracted the disease; 6.1 million of these were considered new cases, while 1.4 million died. TB is the most frequent cause of death due to infectious disease around the world[1]. In Brazil, there is an incidence of 41 cases and 2.4 deaths per 100,000 inhabitants[1].

TB mortality is associated with factors such as co-infection with human immunodeficiency virus (HIV), multidrug resistance, and poor access to health services; moreover, it is closely linked to socioeconomic and demographic determinants[2]. TB is especially prevalent in subpopulations experiencing social vulnerability, such as metropolitan regions with high population density and high poverty levels, where poor sanitation increases the risk of death from TB[2].

Therefore, considering the relationship of TB to social determinants, the identification of areas vulnerable to TB death provides data for preventative actions to control the disease. In this sense, it is important to study the phenomenon from the perspective of spatial risk (SR), considering that Geographic Information Systems (GIS) and spatial analysis are important instruments for managing and planning health policies, as they allow identification of areas where there is a risk of disease[3]. For this reason, this study's objective was to analyze the spatial risk of TB mortality and to verify the association of the high-risk areas with social vulnerability.

An ecological study[4] was conducted in the City of Natal, in the eastern portion of the State of Rio Grande do Norte (RN), which is a priority city for TB control in Brazil, with a population of 810,870 inhabitants. The study was approved by the Institutional Review Board at EERP/USP under CAAE No. 41398915.6.0000.5393 on March 4th, 2015.

Natal is geographically divided into 36 neighborhoods distributed among five administrative regions that correspond to the following Sanitary Districts: North I, North II, South, East, and West[5]. In regard to socioeconomic indicators, the city presents a life expectancy at birth of 71.1 years, a Human Development Index (HDI) of 0.76, a social exclusion index of 0.6, a poverty index of 40.86%, and a Gini coefficient of 0.61[5,6]. In regard to epidemiological data, in 2015 the city presented an incidence of 37.1 cases per 100,000 inhabitants and 2.6 deaths per 100,000 inhabitants (higher than the national rate of 2.4 deaths per 100,000 inhabitants)[7].

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The study's population was composed of cases that resulted in death, the primary cause of which was TB, recorded between 2008 and 2014 in the city's urban area. Data were obtained in March 2015 from Mortality Information System (MIS) - Unified Health System (UHS) as well as the information system of the Brazilian health system on mortality, Department of Health of Natal, RN, Brazil. The classification used corresponds to items A15.0 to A19.9 of the International Classification of Diseases, version 10 (CID10). A total of 895 populated census tracts were considered as analysis units. All census sectors in the City of Natal correspond to urban areas.

The geocoding of cases was initially performed by standardizing and equalizing the addresses of individuals who died from TB in the urban area of Natal, with addresses as contained in the StreetBase® digital map of streets in the Universal Transverse Mercator (UTM) WGS84 projection, acquired via the *Shapefile* (shp) extension from the company *Imagem Soluções de Inteligência Geográfica* and using TerraView version 4.2.2. In cases for which this procedure was not possible, the coordinates of cases were determined using the Universal Transverse Mercator System based on home addresses, using Google Earth™ Version 7.15. SaTScan version 9.4 was used to detect the SR and STR areas concerning TB deaths by applying the statistical scanning technique developed by Kulldorff and Nagarwalla[8].

After establishing the window of analysis, the null hypothesis (H_0) was tested. H_0 assumes there are no areas with high or low risk in the regions, i.e., that all individuals have the same probability of dying due to TB, while H_1 (alternative hypothesis) assumes that one or more regions *z* are areas that present a greater or lower probability of dying from the disease[9].

Poisson's discrete variable model was used for the purely spatial areas, and the following criteria were adopted: no geographical overlap of risk areas, maximum area of risk equal to 50% of the exposed population, and risk area with a circular format and 999 replications.

The spatial scan statistic was performed, adjusting the data for sex, age group, and population in the census sectors and the event's high and low risk. The significance test in the identified risk areas was based on a comparison between the likelihood ratio test results and the distribution under the null hypothesis obtained according to the Monte Carlo simulation[8].

The SR of the areas identified using the scanning statistic allowed information in distinct areas to be compared, indicating how often death caused by TB occurred in the city under analysis. Note that SR was established as the risk of dying from TB in a risk area of the City of Natal in comparison to the risk of dying from TB outside the risk area[8]. Areas with $p<0.05$ and a 95% confidence interval were considered statistically significant. Additionally, thematic maps containing the SR of areas identified in the scanning analysis were developed using ArcGIS version 10.1.

After identifying risk areas for the occurrence of deaths caused by TB, mortality rates (Mr) were calculated taking the sum of deaths (Σ0), stratified according to the variables of age, sex, race, and education level; divided by population size (Σ0) of census tracts of the risk areas; and multiplied by 1/7 [owing to the seven study years (2008-2014)] and then by 100,000, as shown in the formula below:

$$Mr = \left(\frac{\sum 0}{\sum Pop}\right) \times \frac{1}{7} \times 100{,}000$$

The social vulnerability index (SVI) per census tracts, developed by Medeiros[10], was used to characterize high spatial risk areas. The SVI was constructed based on 21 variables obtained from Demographic Census Data 2010 of the *Instituto Brasileiro de Geografia e Estatística* (IBGE); these variables reflect the social disadvantage and infrastructure and are composed of six domains: general characteristics of the residents, characteristics of the surroundings of the residences, residence infrastructure, domicile without a male resident, surroundings without rainwater harvesting, residences in public places without street lighting, and impoverished households. Thematic maps were constructed using ArcGis 10.1 software. Social vulnerability was classified in five classes: very low, low, intermediate, high, and very high.

Additionally, we checked how many census tracts presented the respective SVIs in the areas with high SR identified in this study and, in each risk area, verified the predominant SVI (mode) of that specific risk area. The Bivariate Moran Index (I) was applied to verify the relationship of the spatial risk of dying from TB with the general average of the SVI as well as with six domains of the SVI, using GeoDa 1.0.1 software. For the study of two spatially georeferenced variables, the bivariate Moran index, denoted as I_{xy}, is a spatial correlation index between two variables (X and Y), each obtained in n census tracts[11].

A total of 154 deaths were caused by TB in Natal, RN, Brazil, in which 13 (8.5%) cases were excluded due to lack of information or inconsistent address, totaling 141 (91.5%) geocoded cases: 68 (48.2%) cases using Terraview and 73 (51.8%) using Google Earth.

The spatial risk areas identified in the scanning analysis and characteristics of risk areas are presented in **Figure 1**. After identifying the areas with high or low spatial risk, the TB mortality rate per risk area was calculated according to age, sex, race, and education level (**Table 1**). **Figure 2** shows a map with SVIs per census tracts and the results obtained from Bivariate Moran's Index.

The results show high-risk areas of TB mortality, and these areas presented predominantly sectors tracts classified as moderate social vulnerability. When the association of high-risk areas of TB mortality with domains of the SVI were analyzed, the statistically significant domain was characteristic of the surroundings of the residences (I=0.010; p=0.001), which confirmed some relationship between SR and SVI. Areas with high SR present social inequalities, such as sectors with very high economic standards (classified as having low or very low social vulnerability) as well as those with high social vulnerability[10].

The census tract that comprises the areas of high SR belong to neighborhoods located in the East Sanitary District.

Characteristics of risk areas	Spatial risk		
	High risk 1 (p= 0.026)	High risk 2 (p= 0.003)	Low risk (p= 0.004)
Number of census sectors	17	50	324
Population	11,852	34,405	280,747
Number of deaths	12	23	25
Mortality rate (100,000)	13,400	8,400	1,100
Relative risk	5,770	3.82	0.34
Confidence interval	5.190 - 6.340	3,380 - 4.24	0.08

FIGURE 1 - Spatial risk areas concerning death caused by tuberculosis. Natal, RN, Brazil (2008-2014)

Low SR areas encompassed census sectors that belonged to all the neighborhoods in the South Sanitary District, in addition to those belonging to the East and West Districts.

The East Sanitary District presented the highest demographic density and the second greatest concentration of TB cases in the city[12]. This region also presents a market and commercial area that attracts an intense flow of people, factors that favor the transmission of TB[13]. Additionally, even though this area has more health-related technologically advanced equipment, the Family Health Units cover only 37% of the population, which means Basic Health Units did not cover the majority of the population in this area[13].

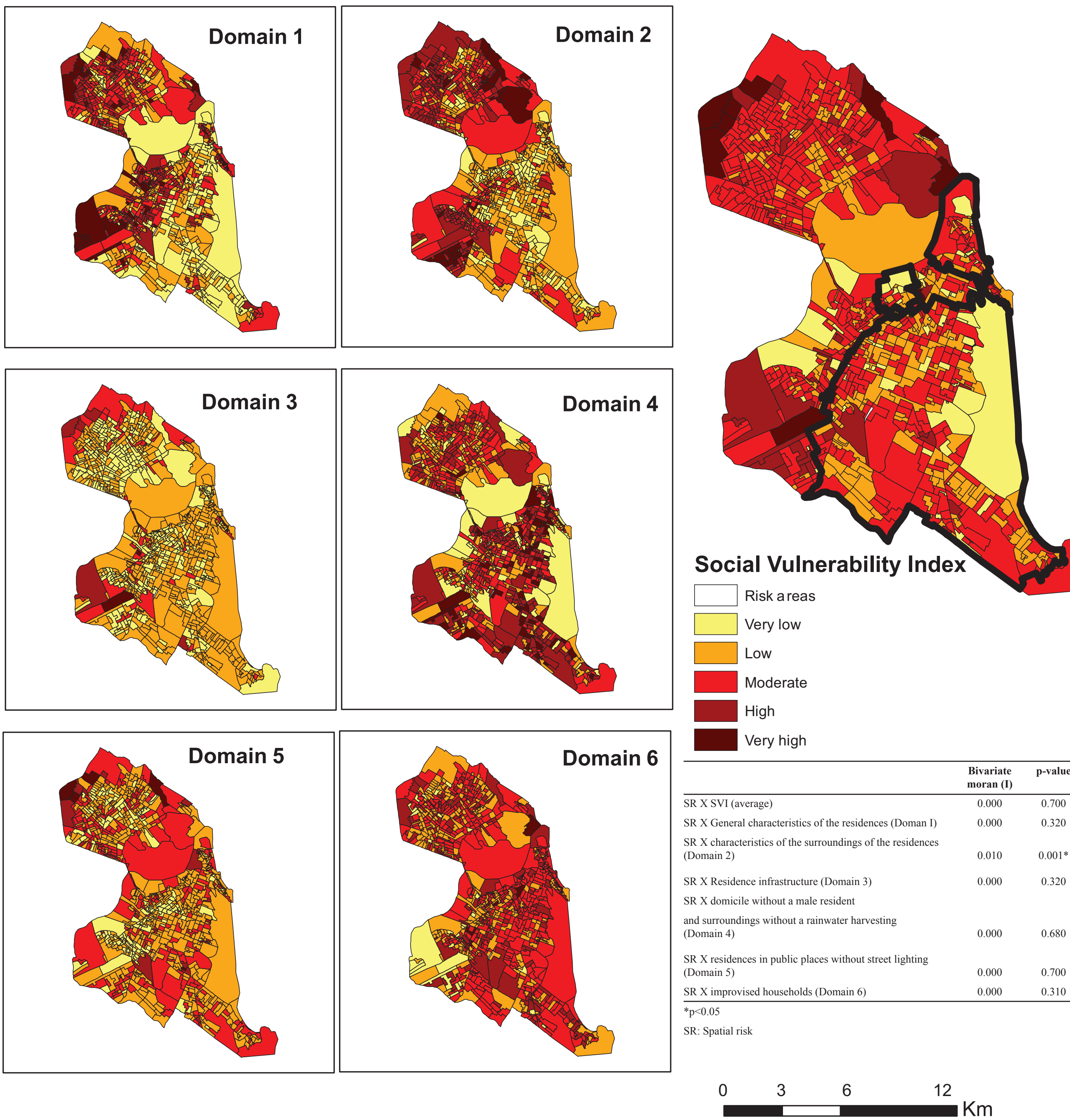
The West District has the second lowest monthly income, while also being the second most populated and the one with the highest concentration of TB cases. Additionally, it exhibits the largest number of people per household and second highest percentage of slums[13]. The District encompasses the highest number of sectors classified as high and very high vulnerability[10].

Those living in the South region, where most of the areas with low SR were located, belong to the medium-high and high socioeconomic categories and have the highest income and lowest demographic density among the districts, also with the

TABLE 1

Annual mortality rate for tuberculosis per 100,000 inhabitants according to sociodemographic variables and risk areas. Natal, RN, Brazil (2008-2014).

Variables	Spatial risk areas	
	high-risk areas	**low-risk areas**
Age (years)	(N=34)	(N=25)
0–14	0.00	0.00
15–59	12.09	0.88
> 60	17.18	4.93
Sex	(N=34)	(N=25)
male	15.68	1.91
female	6.39	0.75
Race	(N=32)	(N=23)
caucasian	6.67	0.84
afro-descendent	16.23	2.57
mixed	10.81	1.66
Education	(N=28)	(N=20)
illiterate	52.89	3.75
literate	6.05	0.92



	Bivariate moran (I)	p-value
SR X SVI (average)	0.000	0.700
SR X General characteristics of the residences (Doman I)	0.000	0.320
SR X characteristics of the surroundings of the residences (Domain 2)	0.010	0.001*
SR X Residence infrastructure (Domain 3)	0.000	0.320
SR X domicile without a male resident and surroundings without a rainwater harvesting (Domain 4)	0.000	0.680
SR X residences in public places without street lighting (Domain 5)	0.000	0.700
SR X improvised households (Domain 6)	0.000	0.310

*p<0.05

SR: Spatial risk

FIGURE 2 - Social Vulnerability Index per census sectors and characterization of risk. Natal, RN, Brazil (2008-2014). **SR:** spatial risk**; SVI:** Social Vulnerability Index.

lowest number of subnormal clusters[13]. In terms of SVI, 50% of census sectors in the South District present low or very low social vulnerability, and none of the sectors present very high social vulnerability[10].

Hence, this study confirms the previously known relationship between TB and high levels of social vulnerability, which is also associated with the social exclusion and marginalization of a portion of the population subjected to poor living conditions, such as a precarious housing situation, malnutrition, and low access to public services[14].

The territory of a given region reflect the economic conditions of the inhabitants; furthermore, these health conditions are subject to social and political inequalities and may further negatively affect the local living conditions, contributing to the generation and continuity of poverty. Hence, recent studies[15] based on the *End TB* strategy have shown the importance of fighting poverty by implementing social protection programs to prevent TB.

With regard to the rate of mortality from TB in the risk areas identified in this study, we highlight that the greatest rates are among the elderly, men, Afro-descendants, mixed race individuals, and illiterate individuals. These results have also been reported in other studies[12].

One of this study's limitations is the use of secondary data; in addition, it is an ecological study, thus it may be subject to the ecological inference fallacy. However, it is important to mention that, despite these limitations, SIM is an information system considered to be the *gold standard* in comparison to other sources.

This study's contributions include the investigation of the relationship of social vulnerability with the high spatial risk of TB mortality. Therefore, this study may contribute to the efforts of managers when they are planning inter-sectoral actions, as well as to aid healthcare practitioners when implementing actions that include the spatialization of cases and factors comprising social vulnerability. This may aid in understanding the context in which individuals affected by TB are found and enable more holistic intervention, in which TB prevention considers not only the biological sphere, but also encompasses social aspects. We believe this is essential to ensure the delivery of integral care.

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Conflict of interest

The authors declare that there is no conflict of interest.

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