

Socio-spatial inequalities related to tuberculosis in the city of Itaboraí, Rio de Janeiro

Desigualdades socioespaciais relacionadas à tuberculose no município de Itaboraí, Rio de Janeiro

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ABSTRACT: *Introduction:* Tuberculosis remains as a global public health problem and its occurrence and distribution is associated with social inequalities. Itaboraí is among the priority Brazilian municipalities for tuberculosis control. The study aimed to combine social indicators into a composite indicator to measure differences in living conditions of the population in Itaboraí, as well as evidence of health inequalities related to tuberculosis. *Methods:* An ecological study, with spatial analysis of tuberculosis and its relation to socioeconomic and demographic status of households. Data were obtained from individuals declared in the Mortality Information System (SIM), notified in the Notification of Injury Information System – SINAN or Tuberculosis Special Treatment Information System – SITETB from 2007 to 2013. *Results:* Evidence indicates association between sociodemographic inequalities and occurrence of tuberculosis in the population. Findings point to a lower percentage of healing and a higher percentage of abandonment and death in areas with high social vulnerability, with a relative risk over twice as high than that found in areas of lower vulnerability. *Conclusion:* The study showed strong evidence that the influence of unequal sociodemographic conditions have a negative impact on health conditions of the population in Itaboraí.

Keywords: Health inequalities. Epidemiological surveillance. Social vulnerability. Spatial analysis.

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RESUMO: Introdução: A tuberculose ainda é um problema de saúde pública mundial e sua ocorrência e distribuição estão associadas às desigualdades sociais. Itaboraí está entre os municípios brasileiros prioritários para o controle dessa doença. Os objetivos deste estudo foram combinar indicadores sociais em um indicador sintético para mensurar as diferenças nas condições de vida da população de Itaboraí, assim como evidenciar prováveis desigualdades em saúde relacionadas à tuberculose. **Métodos:** Estudo ecológico, com análise espacial da tuberculose e sua relação com a situação socioeconômica e demográfica das famílias residentes. Os dados foram obtidos de indivíduos residentes, declarados no Sistema de Informação sobre Mortalidade (SIM), notificados no Sistema de Informação de Agravos de Notificação (SINAN) ou registrados no Sistema de Informação de Tratamentos Especiais de Tuberculose (SITETB), entre 2007 a 2013. **Resultados:** Evidências indicam associação entre desigualdades sociodemográficas e ocorrência de tuberculose na população. Achados apontam menor percentual de cura e maior porcentagem de abandono e óbito em áreas com maior vulnerabilidade social, com risco relativo mais de duas vezes superior ao encontrado nas áreas de menor vulnerabilidade. **Conclusão:** O estudo demonstrou fortes evidências de que a influência de condições sociodemográficas desiguais tem efeitos perniciosos nas condições de saúde da população em Itaboraí.

Palavras-chave: Desigualdades em saúde. Vigilância epidemiológica. Vulnerabilidade social. Análise espacial.

INTRODUCTION

The World Health Organization (WHO)¹ defines social determinants as social conditions in which people live and work. Social determinants of health (SDH)² are economic, social, cultural, ethnic/racial, psychological and behavioral factors that interfere in the onset of diseases. Inequity in health is an inequality that should not exist, since it is avoidable, unfair and unnecessary³. The fundamental premise of equity is “social justice”, passing by the processes that reveal inadmissible disparities in health of socially unequal populations^{4,5}.

Health problems related with infectious diseases, such as tuberculosis (TB) and the Acquired Immunodeficiency Syndrome (AIDS), still persist in the scenario of morbidity found in the country⁶. Some determinants of this scenario is the permanence of structural problems, precarious life conditions and continuous harm to the environment.^{7,8}

Recent studies reinforce the assumption that there is a socioeconomic gradient associated with the occurrence and distribution of TB, considered as a public health issue^{9,10}. An important indicator of inequity is the difficulty to access adequate and opportune treatment¹¹. Itaboraí is among the priority Brazilian municipalities for TB control, since it is in the area comprehended by the Petrochemical Complex of the State of Rio de Janeiro (COMPERJ)¹².

The objectives of the study were:

1. to combine social indicators into a synthesized indicator to express the differences in the life conditions of the population; and

2. to show probable inequalities related with the epidemiological profile of TB between neighborhoods, using the technique of the environmental signature related with the incidence of TB in an environment of Geographic Information System (SIG).

METHODOLOGY

Ecological study whose units of analysis were 71 neighborhoods of Itaboraí, conducted a spatial analysis of cases of TB and the relationship with the socioeconomic status of the families living there, mapping vulnerabilities by socioeconomic status and measuring inequalities in the incidence rates between neighborhoods. Data were obtained from the inhabitants, declared in the Mortality Information System (SIM), notified in the Information System for Notifiable Diseases (SINAN), or registered in the Information System of Special Treatments of Tuberculosis (SITETB), between 2007 and 2013.

Itaboraí belongs to the Metropolitan Region of Rio de Janeiro, with an area of 423.95 km² and population density of 514.42 inhab/km². From 2000 to 2010, its population grew at an average annual rate of 1.63% — in Brazil, this rate was 1.17%. The Human Development Index (HDI) was 0.693, in 2010, which places Itaboraí in the median range of development. The estimated population in 2016 was 230,786 inhabitants¹³. The city also has high incidence rates of TB, with expressive changes in the urban area, coming from the installation of COMPERJ¹⁴.

INCLUSION AND EXCLUSION CRITERIA

A new case was the one whose notification presented the field “type of entry” as “new case” or “does not know”, in the period between January 1st, 2007, and December 31st, 2013. The exclusion criteria were:

1. Cases of duplicity;
2. Cases of entry for recurrence, re-entry or transfer;
3. Cases whose outcome is “change in diagnosis”¹⁵.

STATISTICAL ANALYSIS

Linear regression models were used, according to similar studies,^{16,17} adjusted for the mean of specific incidence rates, in the period of implementation of COMPERJ (2007 – 2013). Secondary data from the Municipal Secretariat and State Secretariat of Health were used, as well as information about geographic and socioeconomic conditions from the Brazilian Institute of Geography and Statistics (IBGE).

The methodological approach was based on:

1. construction of the Social Vulnerability Index (SVI);
2. linkage of databases; and
3. mapping of new cases with geoprocessing.

The theme map of SVI used the digital database per census sector¹⁸. Using geoprocessing techniques, the tool Dissolve, SIG ArcGIS, census sectors and the set of attributes were aggregated to create a cartographic base per neighborhood (unit of analysis). The data of the census sectors were transferred to the respective neighborhoods, being used as a reference both for analyses involving the cartographic base and those operating over socioeconomic and demographic elements.

Considering a probable variation in the age structure of the population, by an indirect method, the following were calculated: incidence rate of neighborhoods, adjusted by age, using the municipality's rate as pattern. After the neighborhood stratification, according to social vulnerability, the cumulative incidence of the population in the middle of the period (census 2010) was calculated¹⁹, examining the behavior of the rate and the stratum-relative risk.

SVI is the synthetic index of socioeconomic and demographic indicators per neighborhood. Like the Paulista Social Vulnerability Index (PSVI)^{20,21}, the SVI identifies areas in accordance with gradients in vulnerability in the population. The components of SVI are identified in Table 1. In the statistical data approach, the factor analysis was used and defined the main components, generating two scores — socioeconomic factor and demographic factor —, employed as independent variables in the regression.

Table 1. Variables associated with the subjacent dimensions and respective correlation values (factor loads).

Variables	Factors	
	Socioeconomic	Demographic
% of households with income of up to ½ minimum wage	-0.892	
Per capita household income	0.870	
Mean income of the woman in charge	0.836	
% of households with income of up to ¼ of the minimum wage	-0.830	
% of literate people in charge	0.728	
% of people in charge aged from 10 to 29 years		0.924
Mean age of people in charge		-0.880
% of women in charge aged from 10 to 29 years		0.862
% of children aged from 0 to 5 years		0.573

Extraction method: Analysis of main behaviors; Rotation method; Varimax with Kaiser Normalization.

The factor analysis followed these conditions²²:

1. All variables were continuous;
2. Method of extraction of factors by main components; and
3. Rotation of factors using the Varimax orthogonal method.

The Kaiser criterion (KMO) of the sample was 0.744, higher to the critical threshold of 0.600. The Bartlett's test (BTS) was statistically significant ($p < 0.000$). The choice was to analyze the main components because of the facility to sum up the set of data. The declivity diagram was used to analyze the dispersion of factors (two were selected for the abrupt reduction in variance). The Varimax rotation tried to minimize the number of variables with high load in each factor.

The normality of continuous variables was assessed by the Kolmogorov-Smirnov test. Associations between independent variables and the mean incidence rate of TB were tested by simple and multiple linear regression. Explanatory variables that did not present collinearity, assessed by the VIF test (variance inflation factor) were introduced by the model and selected by the Backward Method. In the final phase, it was possible to observe the normality of the residuals using the Shapiro Wilk test ($p > 0.05$), and absence of heteroskedasticity.

Relative risk (RR) and confidence intervals were used to assess the relationship between the strata, according to vulnerability and incidence. Categorical variables were compared between the groups by the χ^2 test and the Fisher's test. The significance level in the analyses was 5%. The data were analyzed with the Statistical Package for the Social Sciences (SPSS) 21.0.

The list of records used the software RecLink III²³ to carry out the probability method, based on the conjoined use of common fields of databases — for example, name, sex and date of birth —, in order to identify the probability that a pair of records is referring to the same person.

For the verification of deaths, all of those that had as a basic or associated cause the codes A15 – A19 (10th review of the International Classification of Diseases – ICD) were selected. *Linkage* was conducted in five steps, according to a specific blockage protocol²⁴.

For the environmental signature, there were thematic maps referring to the variables of SVI and rates of TB (density of points), in which each point corresponds to one case per one thousand inhabitants. SIG ArcGIS 10.0 was used to create vectorial thematic maps, then transformed in images, exported to SIG Vista Saga and georeferenced in the raster format; the extraction of the environmental signature was conducted by using the signature tool of the system. With the environmental signature, based on the socio-economic and demographic variables, it was possible to identify in which strata the TB rate was most expressive²⁵.

The use of an environmental signature occurred similarly to the spectral signature in remote sensing, given the possibility to identify objects because of the unique characteristics of the spectral responses of each target. Therefore, the configuration of the mean spectral behavior of a phenomenon will distinguish it from other objects^{26,27}.

The environmental signature looked for unique aspects of the incidence of TB in a SIG environment, using plans of georeferenced information, represented by socioeconomic and demographic variables of the SVI. It was possible to identify in which strata, represented by the scales of measurement of the different variables, the incidence was more representative. Being a heuristic procedure²⁵ based on empirical proof about the possible causal associations between the environmental variables, the use of this technique allows associations between the variables expressed in the different scales of measurement, both numeric and categorical.

The environmental signature assumes that the event of interest is a target or a ground truth, with territorial expression and specific socioeconomic characteristics. Therefore, a situation of health translates itself as a manifestation of the location²⁸.

The attributable risk (AR) and the population attributable risk (PAR) were chosen because the former measures the excess risk in the group exposed associated with exposure, whereas the latter is the measurement of the association influenced by the prevalence of the factor in the general population, measuring the percentage reduction of cases that can be prevented if the risk factor is removed. The AR in the total population is important because it allows knowing which percentage of the event will be reduced by efficient measures of prevention and control²⁹.

This project was approved by the Research Ethics Committee (CEP) at the National School of Public Health (ENSP) (process n. 682.428/2014).

RESULTS

In Table 1, KMO is observed and used in the analysis of the main components, with two factors: the first one with eigenvalue, of 4.17, and 46.37% of variance; and the second one with eigenvalue of 2.26, and 25% of the variance. These two factors explained 71.47% of the variability found among the original variables.

As to the number of cases, some authors²² suggest samples superior to 50 observations, or a ratio between the number of cases and the number of variables exceeding five to one. In this study, the number of neighborhoods accounted for 71 units, using nine variables in the factor analysis, leading to ratio that exceeds seven cases to one.

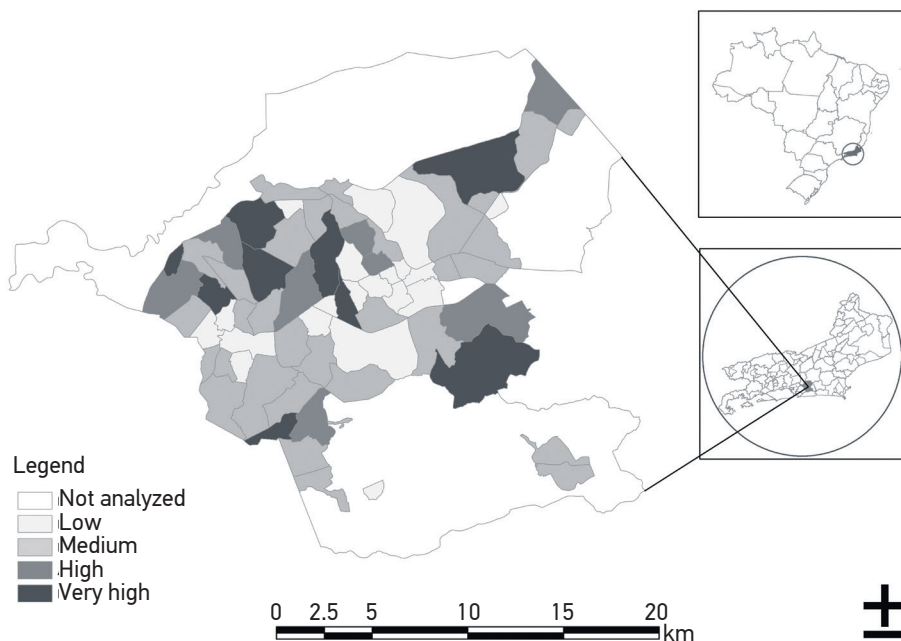
According to the SVI classification, the number of categories was clustered in: low, mean, high and very high vulnerability (Figure 1), and that categorization identified the groups of neighborhoods in this study. The limits of each neighborhood were defined by the gray line. Some areas did not have enough information in the Census and were not included in the analysis, especially the North area in the COMPERJ.

The SINAN database had 1,182 cases, being 957 “new cases” of TB in all forms (pulmonary, extrapulmonary TB or both). Among the records, 14 had duplicity (double notification of a person in the same period of treatment), leaving 943 identified cases.

This study verified 79 death records, and only 25 (31.6%) of these were found in SINAN notifications. By adding the 54 deaths declared in SIM to the 943 cases of SINAN, there were 997 records. Of these, 159 were excluded (88 with ignored address and 71 with incomplete information about the address). Among the excluded records, most (28.4%) were aged from 30 to 39 years and were male (68.0%). The cumulative incidence rate of the city was 442.8 cases per 100 thousand inhabitants.

In multiple regression, the dependent variable was the mean incidence rate of TB. The independent variables were: socioeconomic factor; demographic factor; household density (five or more people per household); and ratio of sexes in cases of TB. After the confirmation by the Backward Method³⁰, two factors of the analysis of the main components remained (socioeconomic and demographic). The final equation was: [Incidence Rate of TB = 95.57 – 30.6 (socioeconomic) – 31.9 (demographic)].

The resulting model (Table 2) presented an adjusted coefficient of determination (R^2) that explained 13.8% of the variability in the mean incidence rate of TB ($R = 0.413$ and adjusted $R^2 = 0.138$). There was an inverse correlation between the rate of TB and predictive variables: socioeconomic ($\beta = -30.6$; $p < 0.05$) and demographic factor ($\beta = -31.9$; $p < 0.05$). That is, the higher the socioeconomic level, the lower the incidence of TB in the period. And the higher the proportion of children and young women in the household, the lower the incidence. In the model, the mean incidence rate is equal to 95.57 (general mean),



Source: Map elaborated based on the data publicized by Census 2010 and the Brazilian Institute of Geography and Statistics (IBGE).
 Figure 1. Map of stratified neighborhoods according to the municipal Social Vulnerability Index – Itaboraí 2014.

when predictive variables are equal to zero. For each increase of unit in the socioeconomic and demographic factors, there was a reduction of 30.6 and 31.9 points in the mean of the response variable.

In Table 3, neighborhoods with “high” and “very high” vulnerability were combined in a single category (high). The final configuration of neighborhoods by SIV was: neighborhoods of low (20); medium (31) and high vulnerability (20). As to new cases, the risk of TB was 33% lower (RR = 0.67) in neighborhoods with medium SVI ($p < 0.001$) in relation to the group with low SVI. For the percentage of cure, relative risk was 32% lower (RR = 0.68) in neighborhoods of medium vulnerability ($p < 0.001$), whereas in neighborhoods with high vulnerability, the risk (RR = 0.78) was 22% lower ($p < 0.001$). As to the percentage of abandonment there was twice as many risks (RR = 2.23) in the neighborhoods with high vulnerability ($p < 0.05$). The proportion of deaths showed risk almost twice as high (RR = 1.98) in neighborhoods with high vulnerability ($p < 0.05$) in comparison to those that are not exposed (low SVI).

There was no association for the percentage of HIV (Human Immunodeficiency Virus) among neighborhoods, but it is important to mention that almost half of the risk of the coinfection TB/HIV was found in neighborhoods of medium and high vulnerability (RR = 0.52 and RR = 0.57). As to the risk of multi-resistant TB (MRTB), there was no significant association between neighborhoods.

In the analysis of ARs (Table 3) the following stand out: lower population risk (18.5%) for new cases in neighborhoods with mean SVI; lower probability of attributable cure (AR = 22.9% and AR = 15.8%) to those exposed (medium and high SVI); percentage reduction of the number of healed cases in the population (PAR = 14.5 and 10.8%), with medium

Table 2. Analysis of simple and multiple linear regression between the mean rate of tuberculosis and socioeconomic and demographic factors in the neighborhoods of Itaboraí, 2007 to 2013.

Variable	Non-adjusted regression coefficient	p-value	R ²
Simple regression			
Socioeconomic factor	-18.19 (-42.27; 5.88)	0.136	0.033
Demographic factor	-24.56 (-48.30; -0.30)	0.043	0.060
Household density	-1.05 (-6.89; 5.71)	0.352	0.023
Gender ratio TB	-0.15 (-1.82; 0.92)	0.777	0.018
Multiple regression	Adjusted coefficient	p-value	Adjusted R²
Backward Method			
Socioeconomic factor	-30.56 (-57.67; -3.44)	0.028	0.138
Demographic factor	-31.95 (-58.96; -4.95)	0.021	

R²: coefficient of determination; TB: tuberculosis.

and high SVI; increasing percentage of abandonment in neighborhoods with high SVI (PAR = 37.8%); and increasing percentage of deaths in neighborhoods with high vulnerability (PAR = 32.5%). All statistics were obtained by the χ^2 test and by Fisher's exact test³¹.

In Figure 2, the percentage of the main variables analyzed according to the environmental signature were verified (vulnerability map). The levels of aggregation of the variables, according with the incidence rate of TB, were defined by adapting the natural breaks method for the intervals.

It was observed that neighborhoods with the highest percentage of young women responsible for the household (17.30 – 37.72) had lower proportion of area including records of cases (4.21%). The neighborhoods with a higher number of people aged between 10 and 29 years (16.27 – 31.76) presented 7.38% of the area with record of cases. Neighborhoods with higher household income per capita (618.30 – 1,156,27) and higher mean income of the women in charge (1,339,08 – 2,263,58) had 8.55 and 9.44%, respectively, of an area with new cases (Figure 2).

Table 3. Cases of tuberculosis coming from linkage and measures of association according to the social vulnerability of neighborhoods in Itaboraí, 2007 to 2013.

SVI	(n)	Pop.	RR (95%CI)	AR (95%CI)	PAR (95%CI)	p-value
Low ^a	297	67,415	1	–	–	
Medium ^a	251	85,132	0.67 (0.56; 0.79)	0.15 (0.2; 0.1)	18.5 (11,6; 24.3)	0.001
High ^a	290	62,259	1.06 (0.9; 1.3)	0.03 (0.05; 0.10)	2.7 (-5,1; 10.4)	0.499
Low ^b	215	297	1	–	–	
Medium ^b	124	251	0.68 (0.6; 0.8)	22.9 (30.9; 15.0)	14.5 (9,6; 18.9)	0.001
High ^b	164	290	0.78 (0.7; 0.9)	15.8 (23.5; 8.2)	10.8 (5,7; 15.4)	0.001
Low ^c	11	297	1	–	–	
Medium ^c	13	251	1.4 (0.6; 3.1)	1.5 (-2.1; 4.9)	15.4 (-20,5; 51.4)	0.400
High ^c	24	290	2.2 (1.1; 4.5)	4.6 (0.7; 8.4)	37,8 (8,2; 67,5)	0.019
Low ^d	14	297	1	–	–	
Medium ^d	18	251	1.5 (0.8; 2.9)	2.5(1.5; 6.5)	19,8 (11,5; 50.1)	0.222
High ^d	27	290	1.98 (1.1; 3.7)	4.6 (0.5; 8.7)	32,5 (4,7; 60.3)	0.029
Low ^e	25	297	1	–	–	
Medium ^e	11	251	0.52 (0.3; 1.0)	40.3 (8.1; 0.0)	21,9 (0,9; 35.6)	0.057
High ^e	14	290	0.57 (0.3; 1.1)	3.6 (7.6; 0.4)	21,1 (2,3; 35.8)	0.081

^a%new case; ^b%cure; ^c%abandonment; ^d%death; ^e%HIV; (χ^2 /Fisher test)³¹; SVI: Social Vulnerability Index; RR: relative risk; 95%CI: 95% confidence interval; AR: attributable risk; PAR: Population attributable risk.

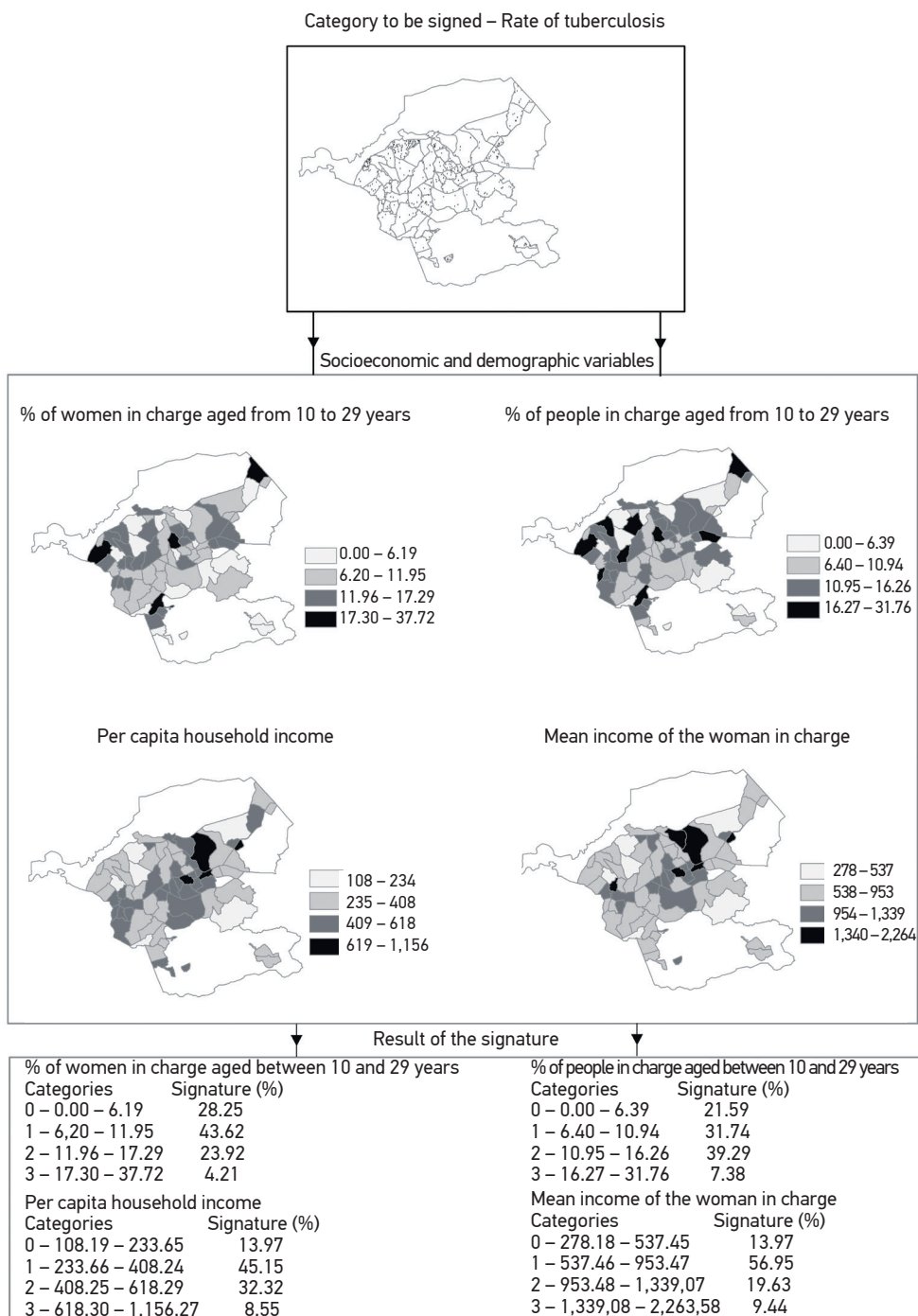


Figure 2. Proportional distribution (%) of the main variables analyzed according to the environmental signature method in the social vulnerability map. Itaboraí, 2007 – 2013.

DISCUSSION

The results of the analysis suggest an association between sociodemographic inequalities and the occurrence of TB in the population of Itaboraí. The estimations found indicate that the higher socioeconomic status and the higher proportion of children and young women in the households, the lower the incidence of TB in the period. There is a lower percentage of cure and higher percentage of abandonment and death in areas with more social vulnerability, with relative risk values twice as high as those in the lower vulnerability areas. The results also show social and spatial inequalities related with the incidence of TB, which corroborate findings in other studies^{14,32}.

Important information about government income transfer programs available in other studies¹⁴, contributed with the outcomes of the analyses in this study.

The WHO points out that the main social determinants responsible for the occurrence of TB at a global level are social inequality, AIDS and the constant migration between regions^{33,34}. It was possible to predict that areas with worse life conditions presented with higher number of cases of TB and diseases related with poverty. There was also prevalence of cases in adults and in the male sex, as reported in the global literature³⁵.

However, some neighborhoods with low vulnerability showed high incidence rates of TB, even with adjustment by age. A possible explanation is that neighborhoods are not homogeneous clusters, with sectors in different socioeconomic conditions. Another possibility is the implementation of COMPERJ, which generated social change for the search of better life conditions, with migration of workers to central neighborhoods, due to the higher level of urbanization, access to services and health care.

A recent study³⁶ showed that 54% of the patients registered in the Tuberculosis Control Program (PCT) never received a household visit from the professional following up the treatment. Also, 62% of the individuals claimed they paid for transportation until the health unit, revealing problems in the provision of transportation. This information indicates that aspects related with the surveillance of the condition and the management of health services are determinant to understand the epidemiological picture.

There was no association between the percentage of new cases of positive TB and HIV, however, the estimations found in neighborhoods of medium and high vulnerability represent about half the risk of coinfection. These findings are in accordance with those in other studies, which suggest there is discrimination when seropositivity is diagnosed, inducing the patient to look for access and treatment in health units that are further from the household^{37,38}.

Differences regarding the access and the stigma coming from the HIV infection are probable sources of bias in epidemiological analyses, because the notification depends on the proper investigation of the case. Also, the reception of these patients should consider precarious social conditions and the emotional impact generated by the TB/HIV comorbidity, usually greater than that experienced by TB individually³⁹.

Regarding the deaths by TB, the highest relative risk in the neighborhoods with high vulnerability highlights the importance of the epidemiological surveillance in the

interruption of the chain of transmission⁴⁰. Of the total of deaths, only 31.6% were notified in SINAN. That is, 68.4% were unknown by the PCT, and supposedly none of the contacts was assessed.

SIG allows the recovery of the location based on the selection of a piece of information, and vice-versa. This ability can be used to identify cases coming from primary or secondary data, allowing the elaboration of environmental signatures. Once the occurrence of interest is defined — probable association between sociodemographic determinants and occurrence of TB —, the database can be consulted regarding the important characteristics of the target-area, defining its signature, recognizing the area of occurrence and the coverage of georeferenced information plans²⁵.

The technique of environmental signature is different from multivariate analyses and SVI, since it is associated with the georeferenced data base (matricial structure) and because it can operate and identify attributes/topology, expressed in different scales (ratio, interval, ordinal, nominal). The technique enables the transit between different information plans at the location of the event, identifying its singularities.

The data of the environmental signature corroborate findings in several scientific studies¹⁶, in which the variables related with gender (male), age group (25 – 49 years), lower income and schooling were associated with TB significantly, revealing inequality in the access to information and higher exposure of the male population.

An important limitation of the study refers to the adjustment by age. Adjustment by gender would also help correct possible biases related with the different strata. The gender ratio was used for cases of TB in the linear regression to overcome this limitation.

To use clustered data, ecological studies are limited by secondary sources, for example, quality control restriction and discrepancy of data coming from information systems. The lack of information from the municipality of origin in SINAN, SITETB and SIM also prevent deeper analyses about migration. In other investigations^{11,41}, the collection of complementary data in the TB Record Book and in the Laboratory Record Book contributed with monitoring and the feedback of systems.

By using AR and PAR, this study tried to measure the percentage of cases that could be prevented if the causal factor were neutralized, being an important measure to implement public health policies⁴².

CONCLUSION

The study demonstrated strong evidence that the influence of unequal sociodemographic conditions tends to produce pernicious effects on the health conditions of the population in Itaboraí. The conclusion is that the control and reduction of inequalities in the occurrence of TB are based on the need to search for more knowledge about its determinants and use of new investigation strategies.

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