

Spatiotemporal pattern and indicators associated with suicide

Padrão espaço-temporal e indicadores associados ao suicídio

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ABSTRACT

Objective: to analyze the spatiotemporal pattern and indicators associated with the occurrence of suicide. **Methods:** ecological study that analyzed the deaths by suicide reported in the Mortality Information System. For temporal and spatial analysis, the Joinpoint and Scan methods were employed, respectively. Multivariate analysis was performed by the Ordinary Least Squares Estimation model, considering $p < 0.05$. **Results:** significant growth in suicide mortality of 4.2% per year was observed. The highest Bayesian mortality rates ranged from 8.90 to 13.49 deaths per 100,000 population. Five statistically significant spatial clusters were identified ($p < 0.050$). The primary cluster encompassed 64 municipalities, with a suicide risk 1.38 times higher ($p < 0.001$). The indicators associated with suicide were Urbanization rate ($\beta = 0.07$; $p = 0.020$) and Employment & income ($\beta = -9.40$; $p = 0.030$). **Conclusion:** there was a significant increase in suicide, and five spatial clusters were identified. The indicators Urbanization rate and Employment & income were associated with the grievance.

Descriptors: Suicide; Epidemiology; Spatial Analysis; Time Series Studies; Ecological Studies.

RESUMO

Objetivo: analisar o padrão espaço-temporal e os indicadores associados à ocorrência do suicídio. **Métodos:** estudo ecológico que analisou os óbitos por suicídio notificados no Sistema de Informações sobre Mortalidade. Para as análises temporal e espacial, foram empregados os métodos *Joinpoint* e varredura *Scan*, respectivamente. A análise multivariada foi realizada pelo modelo *Ordinary Least Squares Estimation*, considerando-se $p < 0,05$. **Resultados:** foi observado crescimento significativo da mortalidade por suicídio de 4,2% ao ano. As maiores taxas de mortalidade bayesiana variaram de 8,90 a 13,49 óbitos por 100.000 habitantes. Foram identificados cinco *clusters* espaciais estatisticamente significativos ($p < 0,050$). O *cluster* primário abrangeu 64 municípios, com risco de suicídio 1,38 vezes maior ($p < 0,001$). Os indicadores associados ao suicídio foram Taxa de urbanização ($\beta = 0,07$; $p = 0,020$) e Emprego & renda ($\beta = -9,40$; $p = 0,030$). **Conclusão:** houve aumento significativo do suicídio, sendo identificados cinco aglomerados espaciais. Os indicadores Taxa de urbanização e Emprego & renda se mostraram associados ao agravo.

Descritores: Suicídio; Epidemiologia; Análise Espacial; Estudos de Séries Temporais; Estudos Ecológicos.

Introduction

Suicide is a serious global public health problem that affects families, communities, and entire countries. Every year, about 800,000 people take their own lives worldwide, which means that there is one self-caused death every 40 seconds. The disease is among the twenty leading causes of death worldwide for all ages and is the second leading cause of death among the young population, aged 15 to 29 years⁽¹⁻²⁾.

Brazil ranks among the 10 leading countries in absolute numbers of suicides⁽¹⁾, since it recorded 205,431 deaths in the period 1990-2015. This represented a 53% increase in the mortality rate, which went from 3.5 to 5.3 deaths per 100,000 inhabitants⁽³⁾. In the country, mortality rates by suicide have shown an upward trend over the years in all regions. Although the South and Midwest regions have the highest rates, the Northeast was the Brazilian region with the highest growth of self-poisoning deaths in the period from 1996 to 2016, given the 104.9% increase in its rates⁽⁴⁾.

Among the states in the region, Piauí stands out, as it showed an increase of 221.7% in deaths by suicide over a ten-year period. Piauí still presents the highest average coefficient of self-poisoning mortality among the nine states of the region (7.77 deaths per 100,000 inhabitants) and, among the 10 northeastern municipalities with the highest rates of the grievance, five are from Piauí. Such statistics show a serious public health problem that occurs in this territory and the need for measures that can reduce the large number of suicidal acts⁽⁵⁻⁶⁾.

Therefore, investigations that evaluate the spatial and temporal distribution of self-caused deaths and their geographic relationship with possible socioeconomic indicators are essential for the understanding of the dynamics of this complex phenomenon and for the support of prevention proposals, both of suicide attempts and of the act of committing suicide. In view of the above, this study aims to analyze the spatiotemporal pattern and indicators associated with the occurrence of suicide.

Methods

This is an ecological study in which the deaths by suicide that occurred in the state of Piauí from 2007 to 2017, registered in the Mortality Information System of the Brazilian National Health System, were analyzed⁽⁷⁾. Piauí is in the Northeast region of Brazil and has 224 municipalities, divided into four development mesoregions: North Piauí, Center-North Piauí, Southeast Piauí, and Southwest Piauí. According to the last demographic census of 2010, its population is 3,118,360 inhabitants⁽⁸⁾.

We included in the analysis all cases of suicide that occurred in the period from 2007 to 2017 that had suicide as the underlying cause in their death certificates. Only those whose codes X60-X84 were cited were selected, according to the 10th International Classification of Diseases (ICD-10). Data collection occurred in the period from July to August 2019.

Initially, a univariate descriptive analysis of deaths by suicide was performed, where sociodemographic variables such as gender, age, race/color, years of schooling, marital status, causes of death according to ICD-10, and place of occurrence were analyzed, considering their absolute and percentage frequencies.

To calculate the crude mortality rates by suicide, the software TabWin v.4.14[®] was used. As numerator of the formula, the number of deaths in each year considered was used and, as denominator, the standardization by the indirect method was used, in which the population of the middle of the period (year 2012) was used. The raw data of each year were tabulated in Microsoft Office Excel spreadsheet to be imported into the Joinpoint Regression Program v. 4.6.0.0[®] software.

The annual percentage variation was calculated with a 95% confidence interval (95%CI), using a 5% significance level to test the hypothesis of the nullity of the annual percentage variation of the series being equal to zero. Thus, negative values of the annual percentage variation indicate decreasing trends and positive values point to increasing mortality trends,

while non-significant values of the annual percentage variation indicate stationary mortality trends⁽⁹⁾. The independent variable was the year of occurrence of the suicide, and the dependent variable was the mortality rate in each year, with calculation and standardization being performed directly in the software.

For the spatial statistical analysis, a digital cartographic base was used with a shapefile vector file obtained from the website of the Brazilian Institute of Geography and Statistics. The base contains polygons that delimit the political borders of the state of Piauí and their respective municipalities, having been georeferenced in the Universal Transverse Mercator projection, *Sistema de Referência Geocêntrico para as Américas* (SIRGAS) 2000 datum. The tabular data with demographic and mortality information were linked to the table of objects in the geographic layer, using standardized geocodes common to both files. The municipalities were defined as the spatial analysis unit.

After calculating the suicide mortality rates in each municipality of the state of Piauí, these were smoothed by means of the Local Empirical Bayesian method. The formation of spatial clusters of deaths by suicide was assessed by means of the purely spatial Scan statistical technique, employing the probabilistic Poisson model and a circular base window that corresponded to 20% of the population at risk, with a significance level of 5%. Conjunctively, maps of the relative risk for the formation of clusters of deaths in the region in the period 2007-2017 were generated.

The Scan method also made it possible to analyze the relative risk for the formation of clusters in the analyzed period. This indicator represents the intensity of the occurrence of deaths by suicide in an area in relation to all the regions analyzed in the study. When the relative risk is > 1 , the relative risk of a specific area is higher than the risk of the entire region analyzed. The software TerraView v.4.2.2[®] was used to calculate the Bayesian statistics. SaTScan v.9.6[®] software was used for the scanning analysis and QuantumGIS v.2.14.17[®] software was used to construct the thematic maps.

To compose the multivariate regression model, 15 socioeconomic indicators of the population of the municipalities of the state were collected from the websites of the Department of Informatics of the Brazilian National Health System⁽⁷⁾ and of the Federation of Industries of the State of Rio de Janeiro⁽¹⁰⁾. The indicators included in the model were: Gini index, unemployment rate, illiteracy rate, urbanization rate, average household income per capita, percentage of poor individuals, proportion of adequate housing, proportion of inadequate housing, proportion of households with adequate sanitation, proportion of households with inadequate sanitation, coverage of the Family Health Strategy, Municipal Human Development Index, percentage of people aged 15 to 24 years old who neither study nor work and are vulnerable to poverty. We also included the indicators Municipal Development Index and Employment & Income, from the Federation of Industries of the State of Rio de Janeiro. The cited indicators were chosen through the epidemiological criterion, after a vast literature review, which aimed to identify the main factors that can influence the occurrence of suicide.

The adjustment of the dependent variable (suicide mortality rate) and independent variable (socioeconomic indicators) was done through the multivariate Ordinary Least Squares Estimation (OLS) model only for the municipalities that showed statistically significant spatial clusters of suicide in the Scan spatial statistics, using the backward method and the epidemiological criterion. Thus, of the 224 Piauí municipalities, 135 were part of the most credible primary cluster or the other clusters considered as secondary. However, of the 135 municipalities that were shown as clusters of deaths, only 106 were statistically significant ($p < 0.05$) and, therefore, only the mortality rates and socioeconomic indicators of these municipalities were inserted into the multivariate model.

The presence of collinearity among the independent variables was verified using the Variance Inflation Factor. The non-collinear variables, that is, with correlation < 0.7 , were inserted in the OLS model,

adopting a statistical significance of 5%. To calculate the multivariate OLS model the STATA v.12® software was used. It should be noted that the results section of this study presents the final regression model, with the variables that proved to be significant.

The ethical and legal precepts were fully respected, as recommended in Resolutions 466/12 and 510/2016 of the National Health Council. The project of this study was approved by the Research Ethics Committee of the State University of Piauí under opinion No. 3,286,816/2019 and Certificate of Ethical Appreciation Presentation No. 07557818.4.0000.5209.

Results

In the state of Piauí, from 2007 to 2017, 2,680 deaths by suicide were recorded, most of them among males' gender (n=2,071; 77.3%), browns (n=1,778; 70.1%), and with seven years or less of schooling (n=1,810; 74.0%). In addition, a significant portion was aged 20 to 39 years old (n=1,219; 45.5%) and single (n=1,221; 47.9%). The most prevalent place of death was the home (n=1,848; 69.2%), and the most common method of death was hanging, strangulation, and suffocation (n=1,957; 73.0%).

The average suicide mortality rate in the analyzed period was 7.7 deaths per 100,000 inhabitants, ranging from 6.9 in 2007 to 9.8 in 2017. Using the Joinpoint method, a stationary trend of mortality by suicide was verified in the period 2007-2013 (annual percentage change: 1.2%; 95%CI: -2.3 - 4.9, with p>0.05), however, a significant increase (p<0.05) of 9.0% per year (95%CI: 2.7 - 15.6) was verified in the period 2013-2017. When considering the entire analysis period (2007-2017), there was a significant increasing trend in mortality of 4.2% per year (95%CI: 1.6 - 6.9).

In map B of Figure 1, it is possible to observe that the map of crude mortality rate by suicide presents an irregular distribution of deaths, resembling a mosaic. However, in map C of Figure 1, a more apparent spatial pattern is observed, with several municipalities presenting Bayesian rates ranging from

8.90 to 13.49 deaths per 100,000 inhabitants, located mainly in the Center-North, Southeast and Southwest of Piauí.

Eight clusters of high suicide mortality rates were identified, five of which were statistically significant at 5%. The primary cluster encompassed 64 municipalities, distributed in an expressive part of the Southeast of Piauí and some municipalities of the mesoregions Southwest and Center-North of Piauí. In turn, the secondary clusters covered 42 municipalities in the Southeast, Southwest, and Center-North regions of Piauí (map D in Figure 1).

On map E in Figure 1, in white are the municipalities that present a relative risk lower than the state average risk. On the other hand, the municipalities highlighted in gray scales have a relative risk higher than the state average. In black are the municipalities of Acauã, Lagoa do Barro do Piauí, Santa Cruz do Piauí, Bertolínea, Vila Nova do Piauí, Santa Filomena, and Manoel Emídio. These have about two to three times the risk of occurrence of deaths by suicide compared to that observed in the state as a whole.

Table 1 presents detailed information on the eight spatial clusters of suicide identified by the Scan method. The primary cluster, that is, the one with the lowest probability of having occurred at random, had a radius of 145.24 km and its municipalities had 1.38 times the risk of suicide compared to the state.

Table 1 – Spatial clusters of deaths by suicide in the period 2007-2017, defined by the purely spatial Scan statistics. Parnaíba, PI, Brazil, 2019

Cluster	No. of municipalities	Radius (Km)	No. of cases	Expected number of cases	Relative risk	LLR*	Value of p†
1	64	145.24	626	484.50	1.38	23.57	<0.001
2	26	76.40	303	212.97	1.47	18.46	<0.001
3	15	60.52	234	162.19	1.48	14.99	<0.001
4	23	103.38	249	188.01	1.35	9.72	0.011
5	7	24.62	96	62.15	1.56	8.10	0.040
6	1	0.00	16	6.04	2.65	0.27	0.272
7	1	0.00	18	8.49	2.12	0.74	0.741
8	1	0.00	12	5.07	2.36	0.91	0.912

*LLR: Log-likelihood ratio test; †P test of the Scan statistic

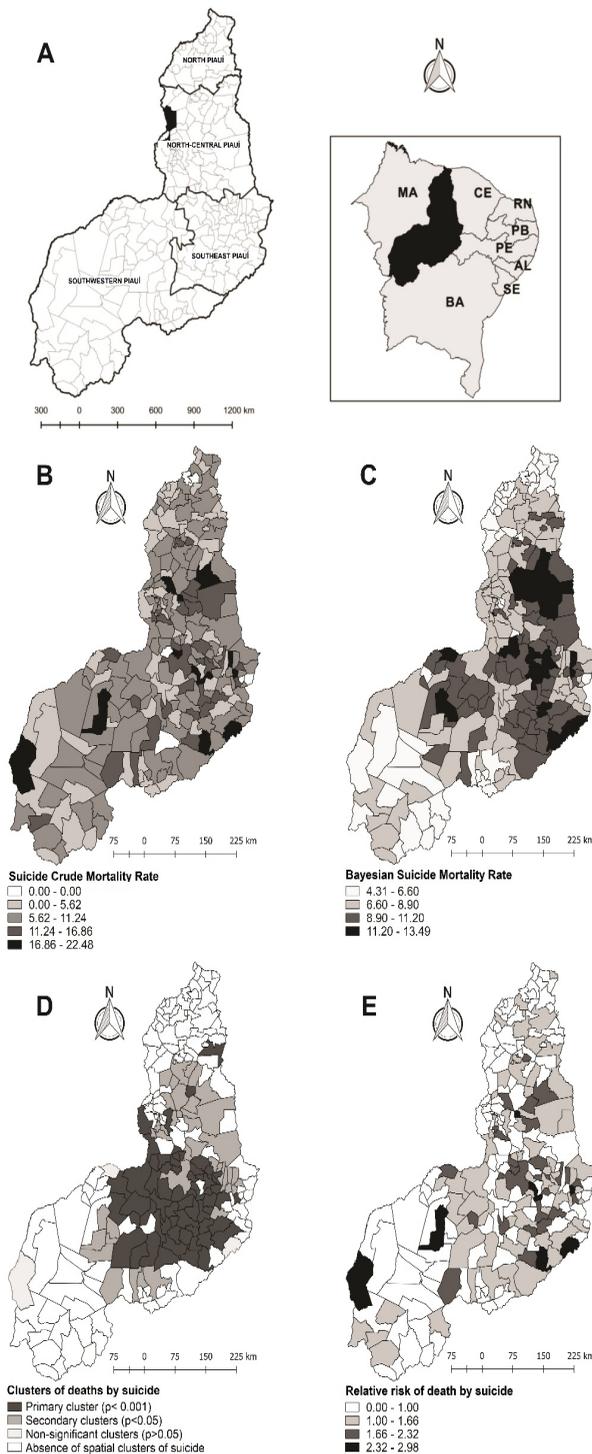


Figure 1 – Geographic delimitation of Piauí and division of its mesoregions (A), maps of the crude (B) and Bayesian (C) mortality rates of suicide, suicide clusters (D) and relative risk of suicide (E) in Piauí in the period 2007-2017. Parnaíba, PI, Brazil, 2019

Table 2 presents the final multivariate Ordinary Least Squares Estimation (OLS) regression model. In the model, a coefficient of determination (R^2) of 0.0781 was observed, which means to say that the set of selected indicators was able to partially explain the variability of suicide by 7.81%. The independent variable Urbanization rate ($\beta = 0.07$; $p=0.020$) showed a directly proportional relationship, while the Employment & income variable ($\beta = -9.40$; $p=0.030$) showed an inversely proportional relationship with suicide mortality, with an average Variance inflation factor (VIF) of 1.06.

Table 2 – Final model of the Ordinary Least Squares Multivariate Regression. Parnaíba, PI, Brazil, 2019

Independent variables*	Coefficient (β)	Suicide mortality		
		T-statistic	95% CI	p-value [†]
Intercept	10.16	5.84	(6.71 – 13.61)	<0.001
Urbanization rate	0.07	2.47	(0.01 – 0.12)	0.020
Employment & Income	-9.40	-2.18	(-17.96 – -0.85)	0.030

*Coefficient of determination (R^2) = 0.0781; [†]OLS regression p-test; CI: Confidence Interval

Discussion

As limitations of this study, we emphasize the use of secondary data that are subject to underreporting and inadequacies during the phases of data collection and feeding the system, due to the presence of ignored or incorrectly identified information^(6,11). Furthermore, it is relevant to highlight that, although the variable Urbanization rate showed statistical significance in the OLS model, this result needs to be interpreted with caution, since its estimated coefficient is very close to zero, demonstrating that the effect of this indicator on the outcome variable is small.

This study contributes to the analysis of the temporal trend of suicide deaths in Piauí, supporting the development and implementation of public policies related to suicide mortality prevention. The spatial approach also contributes as an important tool for a better understanding of the municipalities of Piauí

that have higher risks for the occurrence of this grievance. Furthermore, the study describes the sociodemographic profile of suicide victims and the socioeconomic indicators that were related to the occurrence of suicide, helping managers and health professionals to better direct actions to prevent and control the problem.

It was evidenced that mortality by suicide in the state of Piauí showed a significant growth trend in the period analyzed. This result corroborates a study that analyzed epidemiological data on suicidal behavior in Brazil and observed that all Brazilian regions showed an increase in self-induced mortality rates from 1996 to 2016. According to the study, among all the states, Piauí was the one that presented the greatest variation in the mortality rate of the grievance in the period analyzed⁽⁴⁾.

The literature points out that the growth of suicide deaths in Piauí and in other Brazilian states⁽¹¹⁻¹²⁾ may have resulted not only from the increase in the number of self-caused deaths, but also from a possible improvement in the Mortality Information System, through better completion of death certificates and adequate identification and classification of the underlying cause of death⁽¹¹⁾.

Moreover, the spatial analysis pointed out that statistically significant clusters of deaths by suicide are concentrated in almost half of the municipalities of Piauí. Many of them are characterized by being small and poor, since they have per capita household income equal to or less than R\$140.00 per month⁽¹³⁾. The cities of Acauã, Bertolínea and Manoel Emídio, which have these characteristics and are among the Piauí municipalities that presented, in this investigation, the highest relative risks for suicide in the state, were also among the 10 Northeastern municipalities that recorded the highest rates of self-poisoning deaths, according to a study that analyzed the distribution of suicide in Northeastern Brazil in the period from 2010 to 2014⁽⁶⁾.

It was found that the urbanization rate was directly related to suicide in Piauí, since, as it

increases, the suicide mortality rate is also high in the same proportion. According to the Atlas of Human Development in Brazil, most of the Piauí municipalities have a high urbanization rate, that is, a significant portion of the population lives in urban centers compared to those who live in rural areas. As an example, among some municipalities that showed significant clusters of deaths by suicide are Floriano and Picos, which are characterized by being large municipalities, with most of the population living in urban areas and municipal human development index above the average observed in Piauí⁽¹³⁾.

Although the capital Teresina did not show a pattern of significance and is not part of any of the clusters formed, municipalities in its metropolitan region such as Palmeirais and Altos showed clusters of deaths. Considering that health problems do not respect the boundaries of political-administrative territories, it is necessary to observe with caution the occurrence of this grievance in Teresina, considering that the suicide rate in the city is higher than the national average⁽¹⁴⁾ and, furthermore, it is the second capital of the country with the highest suicide rate in the young population (14.4 deaths per 100,000 inhabitants)⁽⁵⁾.

It is noteworthy that the increase in urbanization may be related to the increase in suicide due to the greater likelihood of social isolation and decrease in community relationships that such isolation engenders. In highly urbanized municipalities there is a tendency for greater distance not only physically, but also emotionally, since social interaction decreases and the feeling of loneliness increases, even with a crowd physically nearby⁽¹⁵⁻¹⁶⁾.

An inverse proportional relationship was found between the Employment & Income indicator and suicide mortality, demonstrating that as this index decreases, self-induced deaths increase. Considering that this indicator, developed by the Federation of Industries System of the State of Rio de Janeiro, is an index that evaluates the generation of income and formal employment in the municipalities, is an index that

evaluates the generation of income and formal employment in the municipalities⁽¹⁰⁾, it is observed that the increase in the occurrence of self-caused deaths may be related to the worsening of job offers and to factors intrinsic to this problem, such as low income and social inequality^(6,14).

Although Piauí has a human development index of 0.646, configuring itself as medium, about eight out of ten municipalities in the state still present municipal human development index classified as very low or low, especially regarding the income and education dimensions, which compose the index⁽¹³⁾. In view of this, an investigation that analyzed the economic impact on suicide mortality rates in Brazil observed that lower levels of the municipal development index were related to increased suicide rates. The authors explain that the increased risk of self-caused death stems from the negative impacts that socioeconomic adversities promote on the quality of life of individuals, mainly by limiting the power of consumption and access to goods and services⁽¹⁷⁾.

Besides the municipal human development index, the Gini index was also significantly related to the occurrence of suicide in a study conducted in Rio Grande do Norte, so that, the higher the development and the higher the income inequality in the area, the higher are the suicide rates. In contrast, in the same study, the per capita income showed an inverse relationship to suicide, which means that higher income levels decrease the occurrence of the grievance⁽¹⁸⁾.

At the international level, a study that analyzed the temporal trend of suicide in Portugal showed increases and decreases in the rates of self-caused deaths over the period 1999-2006. According to the authors, these variations of trend with increase and decrease of mortality may coincide with moments of socioeconomic and financial stability and instability in the territories. This is related to the fact that contexts of crisis and austerity tend to worsen the degree of socioeconomic vulnerability of the individual, increasing the risk of unemployment and financial problems⁽¹⁹⁾.

Related to this, another investigation, which analyzed individual and sociodemographic determinants of suicide, observed that self-induced mortality rates increased as the unemployment rate rose, also noting that the presence of depression and anxiety were statistically associated with suicide⁽²⁰⁾. Thus, the impact of a declining socioeconomic status can generate emotional distress and considerably compromise the quality of life of the individual⁽¹⁹⁻²⁰⁾.

Given the above, it is imperative to formulate public policies aimed at the theme, considering the variables. Moreover, regarding nursing practice, considering the social determinants related to employment and income, in addition to psychological factors, reveals the need for action from the perspective of an expanded clinic, especially in Primary Health Care - the setting for health promotion closest to the individual, family and community. Therefore, it is recommended that further studies be developed for a better visualization of the demands of each region, as well as for effective governmental interventions.

Conclusion

Through the temporal analysis by Joinpoint, significant growth of mortality by suicide in Piauí was evidenced in the period 2007-2017. In the spatial analysis, eight spatial clusters of suicide were identified, with only five being statistically significant. In the multivariate Ordinary Least Squares Estimation model, the indicators Urbanization rate and Employment & income were associated with the occurrence of suicide.

Authors' Contribution

Conception and design of the study, data analysis and interpretation, and article writing: Pereira CN.

Study design, analysis and interpretation of the data, and relevant critical review of the intellectual content: Maranhão TA.

Analysis and interpretation of the data and writing of the article: Silva IG, Silva TL.

Analysis and interpretation of the data and relevant critical review of the intellectual content: Sousa GJB.

Relevant critical review of the intellectual content: Lira Neto JCG, Pereira MLD. All authors approved the final version to be published.

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