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Spatiotemporal pattern and factors related to infant mortality in Northeast Brazil

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Padrão espaço-temporal e fatores relacionados à mortalidade infantil no Nordeste brasileiro

Patrón espaciotemporal y factores relacionados con la mortalidad infantil en el Nordeste de Brasil

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ABSTRACT

Objective: To analyze the spatiotemporal pattern and factors related to infant mortality in Northeastern Brazil from 2008 to 2018.
Method: Ecological study developed with infant deaths that occurred in the Northeast and reported in the Mortality Information System. Non-spatial and spatial regression models were used to identify indicators related to infant mortality.
Results: The mortality rate showed a decreasing trend of 2.1% per year (95% CI: -2.7 – -1.6; p<0.001), with higher Bayesian coefficients concentrated in in municipalities in the interior of Piauí. The variables related to infant mortality were: Gini Index (β = 6.56; p=0.01), Municipal Human Development Index (β = -22.21; p 0.001), dependency ratio (β = 0.16; p <0.001), percentage of people in households without electricity (β = -0.12; p<0.001) and percentage of women aged 10 to 17 who had children (β=0.19; p=0.01).
Conclusion: There was a decrease in infant mortality during the studied period and high Bayesian rates in the interior of Piauí.
Keywords: Infant mortality. Child health. Risk factors. Time series studies. Ecological studies. Epidemiologic studies.

RESUMO

Objetivo: Analisar o padrão espaço-temporal e os fatores relacionados à mortalidade infantil no Nordeste brasileiro de 2008 a 2018.
Método: Estudo ecológico desenvolvido com óbitos infantis ocorridos no Nordeste e notificados no Sistema de Informação sobre Mortalidade. Utilizou-se os modelos de regressão não espacial e espacial para identificar indicadores relacionados à mortalidade infantil.
Resultados: A taxa de mortalidade apresentou tendência decrescente de 2,1% ao ano (IC95%:-2,7 – -1,6; p<0,001), com maiores coeficientes bayesianos concentrados em municípios do interior do Piauí. As variáveis relacionadas a mortalidade infantil foram: Índice de Gini (β=6,56; p=0,01), Índice de Desenvolvimento Humano Municipal (β=-22,21; p<0,001), razão de dependência (β=0,16; p<0,001), percentual de pessoas em domicílios sem energia elétrica (β=-0.12; p<0,001) e percentual de mulheres de dez a dezessete anos que tiveram filhos (β=0,19; p=0,01).
Conclusão: Observou-se diminuição da mortalidade infantil no período estudado e altas taxas bayesianas no interior piauiense.
Palavras-chave: Mortalidade Infantil. Saúde da criança. Fatores de risco. Estudos de séries temporais. Estudos ecológicos. Estudos epidemiológicos.

RESUMEN

Objetivo: Analizar el patrón espaciotemporal y los factores relacionados con la mortalidad infantil en el Noreste de Brasil de 2008 a 2018.
Método: Estudio ecológico desarrollado con muertes infantiles ocurridas en el Noreste y reportadas en el Sistema de Información de Mortalidad. Se utilizaron modelos de regresión espacial y no espacial para identificar indicadores relacionados con la mortalidad infantil.
Resultados: La tasa de mortalidad mostró una tendencia decreciente de 2,1% por año (IC 95%: – 2,7 – -1,6; p <0,001), con mayores coeficientes bayesianos concentrados en las ciudades del interior de Piauí. Las variables relacionadas con la mortalidad infantil fueron: Índice de Gini (β = 6,56; p = 0,01), Índice de Desarrollo Humano Municipal (β = -22,21; p <0,001), razón de dependencia (β = 0, 16; p <0,001), porcentaje de personas en hogares sin electricidad (β = -0.12; p <0.001) y porcentaje de mujeres de 10 a 17 años que tuvieron hijos (β = 0.19; p = 0.01).
Conclusión: Hubo una disminución de la mortalidad infantil durante el período de estudio y altas tasas bayesianas en el interior de Piauí.
Palabras clave: Mortalidad infantil. Salud del niño. Factores de riesgo. Estudios de series temporales. Estudios ecológicos. Estudios epidemiológicos.

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INTRODUCTION

The Infant Mortality Rate (IMR) is considered a classic indicator of the living conditions and health care of a society, since it proves the effectiveness of public health policies and the socioeconomic evolution of the country, being measured through the number of children who die before completing one year of life for every thousand live births (LB)(1).

Over the last few years, there has been a reduction in IMR in Brazil. In 2010, the infant death rate was 17.22 per thousand live births, in 2016, the rate reduced to 12.7 deaths per thousand live births(2). Despite the observed reduction, the country still has high infant mortality rates when compared to developed countries(1), reflecting the unfavorable living conditions of the population and health care, enhanced by regional and socioeconomic inequalities(3).

The existence of inequalities both between social strata and between regions and states, and even between areas of the same city, lead to the identification of territories constituted of population groups at high risk of infant death. In addition, there are differences regarding the availability of resources for health and the capacity to provide services(4). Considering the existence of a direct relationship between infant mortality and socioeconomic conditions, it is clear that the poorest places have an IMR above the national average, with emphasis on municipalities in the Northeast region(5).

It should be noted that most of the health inequities that exist globally reflect the conditions of the process of production and social reproduction. However, not all social indicators have the same degree of importance, since the most relevant are those that lead to changes in the social conditions of the population(6). The network of indicators related to infant mortality is complex and reflects the interaction between several factors, such as: housing, work, income, schooling, social protection, basic sanitation and access to health services(7).

In view of the regional inequalities and the need to point out the factors that are related to infant mortality, especially in the territories that have the highest rates of the problem, it is essential to adopt investigation techniques that evaluate the phenomenon both over time and in space. Thus, it is possible to make inferences and test causal hypotheses that will encourage the planning of interventions that focus on the population where the problem is more alarming and difficult to control(2). Therefore, this study aimed to analyze the spatiotemporal pattern and factors related to infant mortality in Northeast Brazil from 2008 to 2018.

METHOD

Ecological study, which is based on the application of geoprocessing tools and spatial analysis in health whose area of interest was the Northeast region of Brazil. According to the last Brazilian demographic census of 2010, the population of the Northeast was 53,078,137 people, distributed in nine states, namely: Alagoas (AL), Bahia (BA), Ceará (CE), Maranhão (MA), Paraíba (PB), Pernambuco (PE), Piauí (PI), Rio Grande do Norte (RN) and Sergipe (SE), which are home to 28% of the Brazilian population(8).

Secondary health data were used, from the databases of the Mortality Information System (*Sistema de Informação sobre Mortalidade* – SIM) and the Live Birth Information System (*Sistema de Informação sobre Nascidos Vivos* – SINASC), available on the website of the Informatics Department of the Brazilian Unified Health System (*Departamento de Informática do Sistema Único de Saúde* – DATASUS), from the Ministry of Health of Brazil. Data collection took place in November 2019, when all deaths that occurred in children under one year reported in the period from 2008 to 2018 were selected, considering the child's municipality of residence.

The gross data of infant deaths in each year were tabulated in Microsoft Office Excel spreadsheets and imported into the free software Joinpoint Regression Program version 4.6.0.0. The annual percentage change (APC) was calculated with a confidence interval of 95% (95%CI), in which negative APC values indicate a decreasing trend and positive values indicate an increasing trend(9).

Each inflection point added to the model means variation of the linear trend. The model was adjusted assuming that the number of inflection points could range from zero (only one segment) to two (three segments) over the years. A significance level of 5% was determined to analyze the null hypothesis that the APC of the series was equal to zero(9). From this perspective, it was established as the dependent variable the year in which the infant deaths occurred, and the mortality rates in each year, calculated and standardized directly in the program, as an independent variable.

Demographic information and socioeconomic indicators of the population of the Northeastern municipalities, from the last demographic census of 2010, were obtained from the website of the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE). After an extensive literature review and using the epidemiological criterion, fourteen indicators were collected: Gini Index, Municipal Human Development Index (MHDI), Gross

Domestic Product per capita, unemployment rate, illiteracy rate, percentage of people aged eighteen years or more with complete elementary school, dependency ratio, percentage of people in households without electricity, percentage of people in households with inadequate walls, percentage of people in urban households with garbage collection, percentage of people in households with water supply and inadequate sanitation, percentage of poor people, percentage of women aged ten to seventeen who had children and fertility rate.

To calculate the gross infant mortality rates, the software TabWin v.4.14® was used. As the numerator of the formula, it was used the number of deaths among children under one year old in each year considered for this study and, as a denominator, the number of live births in the population of each Northeastern municipality, also for each year, multiplied by 1,000 live births. Gross rates were smoothed by the Local Empirical Bayesian method to correct random fluctuations, especially in municipalities with a small number of inhabitants. For this purpose, a neighborhood matrix was constructed, in which it was used the contiguity criterion(10).

To identify factors related to infant mortality in Northeast Brazil, the selected socioeconomic indicators were inserted into a non-spatial regression model Ordinary Least Squares (OLS) using the step forward method with an input value of 0.1. However, since the classic OLS model does not consider the spatial location of the phenomenon studied, we then proceeded to adjust the Geographically Weighted Regression (GWR) spatial regression model to the statistically significant explanatory variables in the OLS model. Thus, it became possible to identify the variables related to the living conditions of the Northeastern population that may be associated with infant mortality in each municipality in the region, since the problem and its determinants vary according to the area in which they are investigated(11).

The result of the GWR regression is presented in this study in the format of two thematic maps for each socioeconomic indicator: a map for the value of the regression coefficient and another map that represents the statistical significance of each municipality, considering $p<0.05$. The Akaike information criterion (AIC) and the coefficient of determination (R^2) were adopted as parameters to compare the OLS and GWR models and identify which one has the best fit. Thus, the lower the AIC value and the higher the R^2 value, the better the model fit(11).

The TerraView v.4.2.2® software was used to obtain the adjacency matrix and to calculate the Bayesian statistics. The non-spatial OLS regression was performed in Stata v.12® software and GWR spatial regression in GWR v.4.0.9® software. The maps were elaborated using QGIS v.2.14.17® software.

This research was approved by the Research Ethics Committee of the *Universidade Estadual do Piauí* under opinion nº 3.286.819 and CAAE nº 07558218.7.0000.5209. It should be noted that all ethical and legal aspects recommended by Resolutions No. 466/12 and No. 510/16 were respected.

RESULTS

In the Northeast region of Brazil,137,885 infant deaths were reported in the period from 2008 to 2018. From these,76,979 (55.9%) were male children, predominantly brown (n=86,025; 74.5%), eutrophic (n=86,025; 74.5%). n=38,530; 33.2%), premature (n=70,798; 65.3%) and who were in the age group from 0 to 6 days (n=77,744; 56%). About three out of five deaths were caused by conditions related to the perinatal period (n=85,345; 61.8%) (Table 1).

The temporal analysis by Joinpoint showed a statistically significant decreasing trend of infant mortality in all the states of the Northeast region, except Sergipe, which presented a stationary pattern ($p>0.05$). Alagoas was the state that had the most significant reduction in IMR, with a drop of 3.6% per year (95%CI: -4.5- -2.7), followed by Pernambuco, with a reduction of 3.2% per year (CI: -4.2 – -2.2) (Table 2).

In figure 1, it was found that the map of the gross infant mortality rate (map A) showed an irregular dispersion along the northeastern municipalities, without showing an apparent spatial pattern and forming an image with a mosaic appearance due to the instability of the gross values. Given this, smoothing was performed using the local empirical Bayesian method to reduce this dispersion. This method generated more stable indicators that demonstrate a clearer regional pattern of infant mortality (map B).

The thematic map of the smoothed infant mortality rate (map B) shows that most Northeastern municipalities had rates ranging from 13.30 to 18.16 deaths/1,000 LB, with higher rates (23.02 to 27.88 deaths/1,000 LB) predominantly present in municipalities in the interior of Piauí.

Table 3 shows the final linear regression model (OLS) containing the variables related to infant mortality in the Northeast: Gini Index ($\beta=6.56$; $p=0.01$), MHDI ($\beta=-22.21$; $p<0.001$), dependency ratio ($\beta=0.16$; $p<0.001$), percentage of people in households without electricity ($\beta=-0.12$; $p<0.001$) and percentage of women aged ten to 17 years old who had children ($\beta=0.19$; $p=0.01$).

Table 1 – Sociodemographic characterization of infant deaths. Northeast, Brazil, 2008-2018, n= 137,885

Variables*	**n**	**%**
Gender		
Male	76,979	55.9
Female	60,906	44.1
Birth weight		
Extreme low weight	33,999	29.3
Very low weight	16,238	14
Low weight	24,450	21
Normal weight	38,530	33.2
Macrosomia	2,911	2.5
Duration of Pregnancy		
Preterm	70,798	65.3
Term	35,902	33.1
Post-term	1,705	1.6
Age group		
0 to 6 days	77,744	56
7 to 27 days	20,550	14.7
28 to 364 days	40,674	29.3
Cause of death according to ICD-10†		
Chapter I. Infectious and Parasitic Diseases	7,642	5.7
Chapter XVI. Certain conditions originating in the perinatal period	85,345	61.8
Chapter XVII. Congenital malformations, deformations, and chromosomal abnormalities	25,674	18.6
Other	19,224	13.9

Source: Research data, 2018.
* Missing cases were excluded (missing/ignored) for the following variables: gender (n=1,120), birth weight (n=22,887), duration of pregnancy: (n=30,610), age group (n=37) † ICD-10= 10th International Classification of Diseases

Table 2 – Annual percentage change in infant mortality in Northeast Brazil and in the northeastern states from 2008 to 2018

Population	Period	Annual Percentage Change (*IC95%)	P Value	Trend
Northeast	2008-2018	-2,1(-2,7 – -1,6)	<0,001	Decreasing
Alagoas	2008-2018	-3,6(-4,5 – -2,7)	<0,05	Decreasing
Bahia	2008-2018	-2,2(-2,6 – -1,7)	<0,05	Decreasing
Ceará	2008-2018	-2,2(-3,5 – -0,9)	<0,05	Decreasing
Maranhão	2008-2018	-1,0(-1,9 – -0,1)	<0,05	Decreasing
Paraíba	2008-2018	-2,8(-3,9 – -1,8)	<0,05	Decreasing
Pernambuco	2008-2018	-3,2(-4,2 – -2,2)	<0,05	Decreasing
Piauí	2008-2018	-1,9(-2,6 – -1,2)	<0,05	Decreasing
Rio Grande do Norte	2008-2018	-1,4(-2,4 – -0,5)	<0,05	Decreasing
Sergipe	2008-2018	-0,7(-1,8 – 0,5)	>0,05	Stationary

Source: Research data, 2018.
*CI95% = 95% Confidence Interval

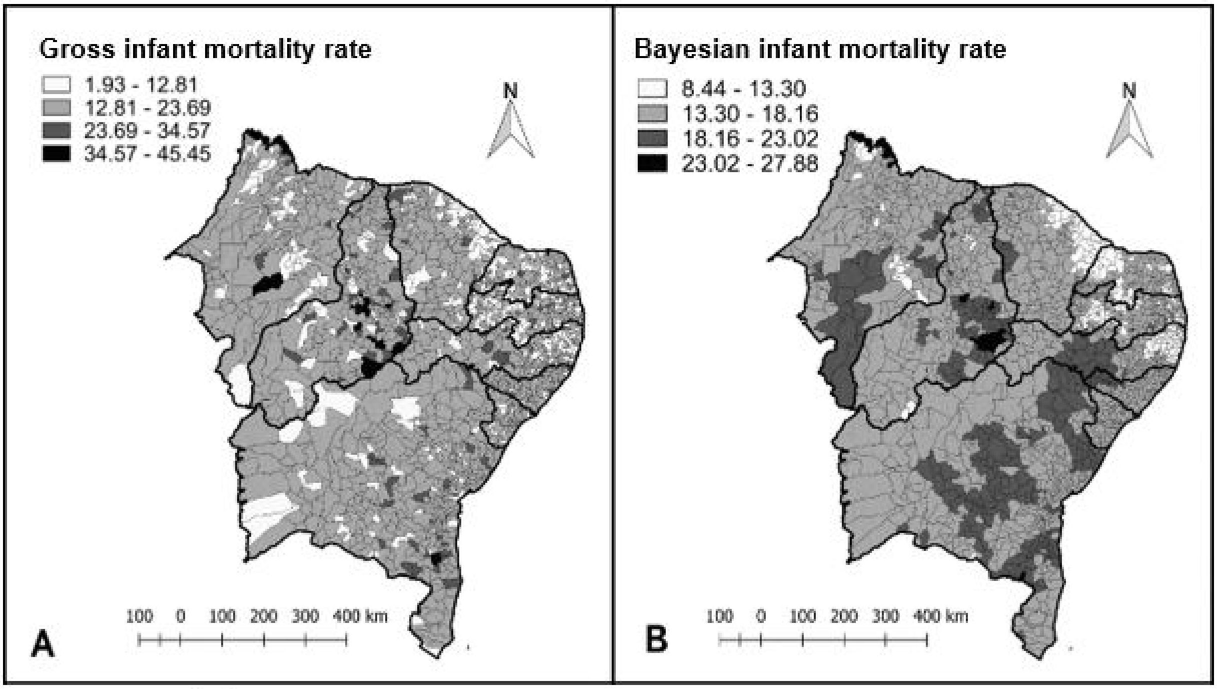
Gross infant mortality rate
1.93 - 12.81
12.81 - 23.69
23.69 - 34.57
34.57 - 45.45
N
100 0 100 200 300 400 km
A
Bayesian infant mortality rate
8.44 - 13.30
13.30 - 18.16
18.16 - 23.02
23.02 - 27.88
N
100 0 100 200 300 400 km
B

Figure 1 – Spatial distribution of the average gross infant mortality rate (A) and the average infant mortality rate smoothed by the local empirical Bayesian method (B). Northeast, Brazil, 2008 to 2018
Source: Research data, 2018.

Table 3 – OLS and GWR regression models of the socioeconomic indicators that influence the infant mortality rate. Northeast, Brazil, 2008-2018

Socioeconomic Indicators	OLS Model			GWR Model	
	*Coeff.	Standard error	P Value	*Coeff.	Standard error
Gini Index	6.56	2.48	0.01	6.56	2.47
MHDI	-22.21	4.51	<0.001	-22.21	4.51
Dependency ratio	0.16	0.03	<0.001	0.15	0.03
People in households without electricity (%)	-0.12	0.02	<0.001	-0.12	0.01
Women aged 10 to 17 years old who had children (%)	0.19	0.07	0.01	0.19	0.07

Source: Research data, 2018.
*Coeff. = Coefficient

It should be noted that the indicators: unemployment rate, illiteracy rate, percentage of people in households with inadequate walls and percentage of people in households with inadequate water supply and sewage, also showed statistical significance in the OLS model, but were not included to the model because they were below 0.1 and, therefore, very close to zero.

In the OLS, the coefficient of determination (R^2) was 10.07 and the Akaike information criterion (AIC) was 10613.26.

The spatial regression model (GWR) of the infant mortality rate was adjusted for the variables presented in the OLS model (Figure 2). When comparing the two regression models, it was observed that the GWR was better adjusted than the OLS model, as it presented AIC of 10484.68 and R^2 of 17.36.

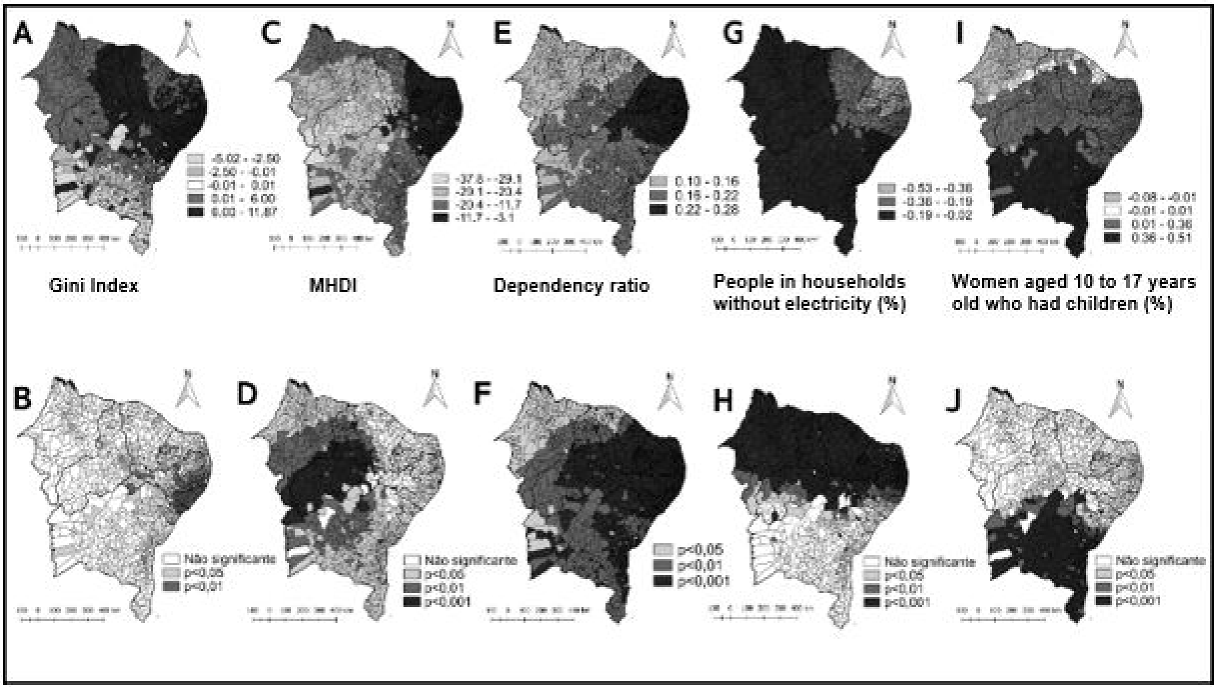
A
-5.02 - -2.50
-2.50 - -0.01
-0.01 - 0.01
0.01 - 6.00
6.00 - 11.87
Gini Index
C
-37.8 - -29.1
-29.1 - -20.4
-20.4 - -11.7
-11.7 - -3.1
MHDI
E
0.10 - 0.16
0.16 - 0.22
0.22 - 0.28
Dependency ratio
G
-0.53 - -0.36
-0.36 - -0.19
-0.19 - -0.02
People in households without electricity (%)
I
-0.08 - -0.01
-0.01 - 0.01
0.01 - 0.36
0.36 - 0.51
Women aged 10 to 17 years old who had children (%)
B
Não significante
p<0,05
p<0,01
D
Não significante
p<0,05
p<0,01
p<0,001
F
p<0,05
p<0,01
p<0,001
H
Não significante
p<0,05
p<0,01
p<0,001
J
Não significante
p<0,05
p<0,01
p<0,001

Figure 2 – Spatial distribution of the estimated coefficients and the significance of the t value associated with the variables: Gini Index, IDHM, dependency ratio, percentage of people in households without electricity and percentage of women aged between ten to seventeen who had children. Northeast, Brazil, 2008 to 2018
Source: Research data, 2018.

Maps A and B showed that in the states of Pernambuco, Sergipe, Alagoas, some municipalities in Ceará, Piauí, Paraíba and Bahia, the Gini Index had a positive and significant association with the dependent variable, demonstrating a directly proportional relationship between the index (social inequality) with the infant mortality rate in these areas (Figure 2).

It was also found that in Maranhão, Piauí, Bahia and West Ceará, the lower the Municipal Human Development Index, the higher the infant mortality rate in these places (Maps C and D). In the entire Northeast region, it was found that the dependency ratio increases as the deaths of children under one year also increase (Maps E and F). In addition, in all states, except Sergipe, it was observed a significant negative association between the variable "percentage of people in households without electricity" and the infant mortality rate (Maps G and H). Maps I and J showed that the variable percentage of women aged ten to seventeen who had children was positively associated with infant mortality in part of Bahia and in some municipalities in the south of Piauí (Figure 2).

DISCUSSION

The socioeconomic factors that predict infant mortality are frequently associated with indicators that reflect the population's schooling, income, and housing conditions, among others. Low maternal schooling strongly affects access to health care and makes pregnant women and newborns more vulnerable, thus contributing to the increase infant mortality rates, since these women have less access to prenatal care or to take care of their health during pregnancy. Income, on the other hand, is an indicator that is directly related to a family's living conditions in relation to access to goods and services(6,12–14).

In this study, it was observed that most infant deaths occurred among male newborns. This result may be related to the slower maturation of the lungs during fetal development in male newborns compared to female newborns, increasing the risk of respiratory infections and, therefore, the risk of death(5,13).

Regarding the duration of pregnancy, prematurity can be related to maternal, fetal, and environmental factors, as well as to the assistance received during prenatal care. Furthermore, it was observed that infant deaths are concentrated in the first six days of life, demonstrating that the early neonatal period constitutes the main component of infant mortality. This reflects the need to consolidate an integrated perinatal care network of primary health care with maternity hospitals and professional qualification, especially regarding labor and birth. In addition, structural changes must occur in the population's living conditions, defined by public health policies(13–15,17).

The local empirical Bayesian analysis map showed that the highest infant mortality rates are in some municipalities in the state of Piauí. The heterogeneous distribution found in the Northeast is similar to that observed in the North region, which are the regions of Brazil with the highest mortality rates in children under one year old(4). However, although the IMR still remains high in the region, the temporal analysis revealed that eight of the nine northeastern states show a decreasing trend in the registration of infant deaths in the studied period.

The results of the GWR regression showed several factors related to infant mortality, among them, the Gini Index, which is one of the most used measurements to measure inequality in income distribution. In this context, it was found that in a significant portion of the northeastern states, the higher the Gini Index, the higher the infant mortality rate in these areas. National studies corroborate this result(7,12), since municipalities with greater income inequalities would have more difficulties in achieving better results in reducing infant mortality.

It was observed in Maranhão, Piauí, Bahia and West Ceará that the lower the Municipal Human Development Index (MHDI), the higher the infant mortality rate. The MHDI follows the same three dimensions as the global HDI, which are: a long and healthy life measured by life expectancy at birth, the ability to obtain knowledge, measured by the average number of years of schooling, and the probability of achieving a decent standard of living, determined by gross national income per capita(15). A study conducted in Brazil highlighted that infant mortality rates were quite sensitive to the MHDIs, noting that the increase in this indicator reduces the mortality of children under one year old(17).

Furthermore, the dependency ratio proved to be a risk factor for infant mortality throughout the Northeast. This indicator relates the large age groups, being measured by the ratio between economically dependent people (young and elderly) and those potentially active. Thus, according to the National Household Sample Survey (*Pesquisa Nacional por Amostra de Domicílios*) – PNAD 2015, the dependency ratio of young people in Brazil reduced significantly, as the dependency ratio of the elderly increased. Thus, changes in the dependency ratio are directly associated with a decrease in fertility and an increase in population longevity. Thereby, the relative decline in the economically active population indicates a loss of this group's capacity to funding groups dependent on the active population(18).

A significant negative association was observed in all states, except Sergipe, between the variable percentage of people in households without electricity and the infant mortality rate. It is believed that this result is related to the increase in access to electricity by the Northeastern population. It is worth mentioning that, in the last two decades, strategies aimed at reducing the population's social differences were developed. Among these strategies, stands out the National Program for Universal Access and Use of Electric Energy – Light for All (*Luz para Todos*). According to the Demographic Census carried out in 2000, there were more than two million rural households without access to electricity in Brazil, which represented more than ten million Brazilians not attended by this service. It was estimated that approximately 90% of these families had an income of less than three minimum wages, living mainly in locations with low HDI, especially in the Northeast region. In 2016, 3.2 million households were benefited, corresponding to 15.9 million people. With this, it is evidenced the improvement in the living conditions of the poorest population(19).

There was a positive association between the variable percentage of women aged ten to seventeen years old who had children and infant mortality in Bahia. The relationship between the mother's age group and infant mortality is well known in the literature, with emphasis on teenage pregnancy and its unfavorable outcomes, such as prematurity, low birth weight and a higher cesarean delivery rate that may be associated(20). In addition, there is evidence that early pregnancy occurs primarily in regions with great social inequalities, in areas characterized by misery and poverty, and in disadvantaged social groups(14).

A study conducted in Brazilian capitals between 2011 and 2012 showed a higher occurrence of infant deaths in newborns of adolescent mothers when compared to young adults(7). In turn, a research conducted in Rio Grande do Sul showed that the reduction in the infant mortality rate is directly related to the decrease in pregnancy between ten to seventeen years of age(20).

Faced with this issue, the early initiation of sexual activities, the lack of knowledge, the way in which issues related to sexuality are treated, in addition to the stigma, both in schools and at homes, may reflect the distancing of preventive and educational actions in concerning to sex education and contraceptive methods aimed at this audience. The growth in the percentage of adolescent pregnancy poses challenges for the health services, as this condition is related to the low use of prenatal care, contributing to the increase in infant mortality(20).

CONCLUSION

Based on the JoinPoint regression analysis, a statistically significant decreasing trend in infant mortality was observed in all states of the Northeast region, except Sergipe, which presented a stationary pattern. It was found that the highest Bayesian rates are located predominantly in municipalities in the interior of Piauí.

Five social indicators that influence infant mortality in the Northeast were identified: Gini index, Municipal Human Development Index, dependency ratio, percentage of people in households without electricity and percentage of women aged ten to seventeen who had children. The GWR spatial regression model showed that these indicators act as risk or protective factors, depending on the municipality investigated. From this perspective, disease prevention strategies should be directed to the municipalities with the highest occurrence of the problem. In these territories, it is necessary to make public health actions more effective, especially those related to prenatal care, childbirth, and newborn care, in addition to ensuring the improvement of the conditions in which populations live, with a special focus in the indicators associated with infant mortality pointed out in this study.

One of the limitations presented in this study is related to the ecological design, as the analysis of variables at the population scope does not necessarily represent an association at the individual level. In addition, the use of secondary data may present inconsistencies regarding the quantity and quality of information. However, it should be noted that such limitations did not make the research unfeasible and do not diminish its importance, but such weaknesses point out to possibilities to be explored in future studies aimed at deepening the theme.

Regarding vulnerability indicators, it is worth noting that, although following IBGE criteria, the data used refer to the 2010 census, which may have changed in the last years.

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