ORIGINAL ARTICLE / *ARTIGO ORIGINAL*

Spatial distribution of hospitalization rates of children due to pneumonia in the Unified Health System, in the municipalities of the state of São Paulo

Distribuição espacial das taxas de internação de crianças por pneumonia no Sistema Único de Saúde, nos municípios do estado de São Paulo

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ABSTRACT: *Objective*: To identify spatial patterns in the distribution of hospitalization rates of children with pneumonia in the state of São Paulo, Brazil from 2009 to 2013. *Methods*: This was an exploratory ecological study with data obtained from DATASUS of hospitalizations of children with pneumonia in the municipalities in São Paulo from 2009 to 2013/ Data on maternal education and family income were obtained and rates per thousand children were calculated and inserted in a database of municipalities obtained from IBGE. Thematic, kernel and Moran maps were constructed for the hospitalization rates and the Moran indices were calculated. The TerraView program was used for spatial analysis. *Results*: A total of 43,809 children were hospitalized in the study period, with a minimum of zero and a maximum of 69,072. The mean rate per municipality was 11.51 ± 8.62 (SD). The Moran index was 0.21 ($p = 0.01$). The thematic map showed clusters in the northern, northwestern, midwestern and southwestern regions of the state; the kernel map showed a higher density of rates in the northwestern and midwestern areas, and the Moran map identified 39 municipalities that deserve the attention of municipal and regional managers. *Conclusions*: Geoprocessing identifies regions with higher hospitalization rates for pneumonia and also municipalities that deserve a high intervention priority.

Keywords: Spatial analysis. Pneumonia. Child health. Geographic information system.

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RESUMO: *Objetivo:* Identificar padrões espaciais na distribuição das taxas de internação de crianças por pneumonia no estado de São Paulo, no período de 2009 a 2013. *Métodos*: Estudo ecológico exploratório com dados obtidos do Departamento de Informática do Sistema Único de Saúde (DATASUS) de internações por pneumonia em crianças relativas aos municípios do estado de São Paulo de 2009 a 2013, dados de escolaridade materna e renda familiar; e foram criadas taxas por mil crianças e inseridas numa base digital de municípios obtida do Instituto Brasileiro de Geografia e Estatística. Foram construídos mapas temáticos, de Kernel e de Moran para as taxas de internação e calculados os índices de Moran. Foi utilizado o programa TerraView para a análise espacial. *Resultados*: Foram internadas 43.809 crianças no período. A taxa média por município foi de 11,51 (DP = 8,62). O índice de Moran foi de 0,21 (p = 0,01). Há aglomerados nas regiões norte, noroeste, centro-oeste e sudoeste; o mapa de Kernel mostra densidade maior de taxas no noroeste e centro-oeste do estado; e o mapa de Moran identificou 39 municípios que merecem atenção por parte dos gestores municipais e regionais. *Conclusões*: O geoprocessamento permitiu identificar regiões com maiores taxas de internação por pneumonia e também municípios que merecem prioridade de intervenção.

Palavras-chave: Análise espacial. Pneumonia. Saúde da criança. Sistemas de informação geográfica.

INTRODUCTION

Acute respiratory infection is one of the 5 main causes of death in children under 5 years of age in developing countries.[1] About 40% of children needing medical attention suffer from acute respiratory infection[2], where community-acquired pneumonia is the most severe, causing 80% of deaths[3,4]. In Brazil, acute lung diseases are responsible for 11% of deaths in children under 1 year old and 13% in the age group between 1 and 4 years[5]. Fifteen countries are responsible for 74% of disease episodes in children under 5, where Brazil ranks 15th[6].

In addition, community-acquired pneumonia accounts for much of the health care costs in Brazil, as it is associated with high hospitalization rates in the country[7,8]. Although there has been a decline in child mortality due to pneumonia in recent decades, it is still a major cause of hospitalization and death in developing countries[5,8-11], being the disease that causes the most deaths in children up to 5 years old in the world[12], approximately two million children according to one study[13].

Hospitalization records for pneumonia from government statistics generated by the Department of Informatics of the Unified Health System (DATASUS) point to pneumonia as the second cause of hospitalizations[14].

In Brazil, in 2013, according to DATASUS, about 250,000 children under 4 years old were hospitalized for pneumonia, and in São Paulo, this number approached 45,000. These hospitalizations cost the Unified Health System (SUS) R$ 170 million for Brazil and R$ 64 million for the state of São Paulo. There were 1,296 and 400 deaths resulting from pneumonia in Brazil and in the state, respectively[15].

Among the various risk factors associated with pneumonia are: low socioeconomic status, malnutrition, low birth weight, lack of breastfeeding, family crowding, environmental pollution, climate variation and passive exposure to cigarette smoke[3,6,8,9,16,17].

In recent years, geographic information systems have been gaining ground in epidemiological studies, identifying spatial patterns for various situations, including those related to health, epidemiology, and child mortality, adding socioeconomic, environmental, and structural health data to the geographic component of the neighborhood relationship between places. Thus, spatial correlation data characterize regional scenarios, allowing the planning of intervention strategies, whether local or regional, and also enabling the analysis of the outcome of this intervention.[8,9,18].

Thus, the aim of this study was to identify spatial patterns in the distribution of mean hospitalization rates for pneumonia in children up to 4 years of age in the municipalities of the state of São Paulo between 2009 and 2013, and also to identify municipalities that merit the attention of municipal and regional health authorities to lower these rates.

METHODS

This was an ecological and exploratory study with data on hospitalizations for pneumonia (ICD-10: J12.0 to J18.9) in children up to four years old, referring to hospitalizations by SUS, according to place of residence. Data from all cities of the state of São Paulo were analyzed. The study period was from 2009 to 2013.

The data considered were those referring to the number of hospitalizations, relating it to maternal education level (up to incomplete elementary school) and family income, obtained from the DATASUS portal[19]. The digital network of 645 municipalities was obtained from the Brazilian Institute of Geography and Statistics (IBGE) 20. Terraview version 4.2.1, available from the National Institute for Space Research (INPE), was used to analyze the information collected. The unit of analysis was the municipality and the hospitalization rate per thousand children up to 4 years old was used. The mean hospitalization rates for children with pneumonia throughout the period and also in the years 2009 and 2013 were calculated, and these mean rates were compared using Student's t-test. The five-year period was chosen to minimize possible fluctuations in the number of cases; and the comparison between the beginning and the end of the period was due to the fact that anti-pneumococcal vaccination was begun in 2010.

The global (Im) and local Moran indices were calculated and thematic maps were then prepared with the hospitalization rates per thousand children—Moran map and Kernel density map—constructed with 150 columns, quartic function and adaptive radius. Maps were also constructed regarding the proportion of families with incomes below half the minimum income and the proportion with low education for the population of each municipality, and Pearson's correlation coefficient was determined.

The Moran index estimates the existence of spatial autocorrelation between the data, that is, if there are clusters of municipalities with high rates and others with low rates. Its values range from -1 to +1 and it can be assigned a significance level (p): the closer the value is to -1, the less autocorrelated are the variables analyzed between themselves; and the closer it is to +1, the more similar are the rates.

The Moran map allows us to identify high value municipalities surrounded by high value ones and low value municipalities surrounded by low value ones. Thus, municipalities with high priority for intervention and others with low priority are identified.

The kernel map is a statistical method for estimating density curves, giving an overview of the intensity of the process in question in all regions of the map, allowing their comparison.

Given that these data are available on the network, without the possibility of identifying the subject, clearance by the Research Ethics Committee was waived.

RESULTS

During the study period, 233,597 children were hospitalized in the state of São Paulo. The mean hospitalization rates for pneumonia per thousand children, by municipality, with their respective standard deviations (SD) and minimum and maximum values, hospitalization, proportion of mothers with low education and proportion of families with income below half the minimum are given in Table 1. The mean hospitalization rate in children for pneumonia per thousand children in 2009 was 25.46 ± 34.68 (SD) and in 2013, 20.46 ± 22.23), being significantly different ($p < 0.05$).

The I_M calculated for hospitalization rate was 0.21 ($p = 0.01$), showing that there was spatial autocorrelation between hospitalization rates for pneumonia in this age group in the municipalities of São Paulo. The I_M for the proportions of family income below half the minimum income and of mothers with low education were 0.54 and 0.30, respectively, with $p = 0.01$ in both cases, also indicating spatial autocorrelation between these rates.

Table 2 presents the Pearson correlation matrix, showing a significant positive correlation between hospitalization rates and proportion of mothers with low education.

Table 1. Mean, minimum and maximum values, and respective standard deviations of the variables hospitalization rate for pneumonia in children up to 4 years old, low maternal education and family income less than half the minimum income. State of São Paulo, 2009 to 2013.

	Mean	SD	Maximum	Minimum
Hospitalization rate	21.78	27.74	388.28	0.26
Low maternal education	18.95	4.61	37.33	6.13
Family income <1/2 MI	36.24	11.61	77.83	9.12

SD: standard deviation; MI: minimum income.

Figure 1 shows the map of hospitalization rates for children under four with pneumonia. It was possible to see that the largest number of municipalities in the state of São Paulo with high hospitalization rates for pneumonia were in the northern, northwestern, midwestern and southwestern regions.

The map of the rates of mothers with low education (not shown) identified the regions of the state with the highest number of municipalities with high proportions of mothers with low education, which were the northern, northwestern, midwestern, southwestern, southern, and also some far eastern parts of the state. The map of the proportions of families with income below half the minimum, also not shown, identified the largest number of municipalities in the southwestern, western, southern and some far eastern regions.

The Moran map (Figure 2) identified areas in the state of São Paulo, from 2009 to 2013; it means that there was a significant occurrence of municipalities with high rates surrounded by municipalities also with high rates (high-high) and of municipalities with low rates surrounded

Table 2. Pearson correlation matrix of the variables hospitalization rate (per 1000 children) for pneumonia in children up to 4 years old, low maternal education and family income less than half the minimum income. State of São Paulo, 2009 to 2013.

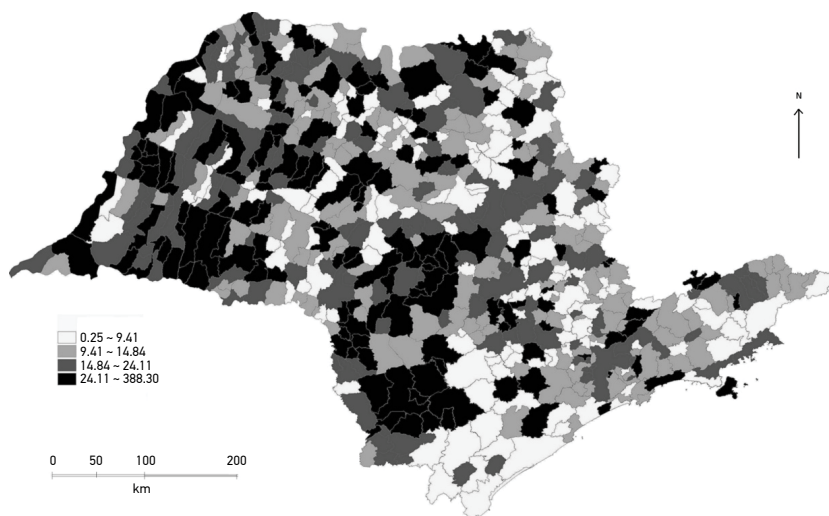|	Income <1/2 MI	Rate	Maternal education
Income <1/2 MI	1		
Rate	0.02	1	
Maternal education	0.38#	0.12#	1

MI: minimum income; #p < 0.01.

Figure 1. Spacial distribution of hospitalization rates per 1000 childrens, in municipalities in the state of São Paulo, in 2009 to 2013.

by municipalities with with low rates (low-low). High-rate municipalities surrounded by high-rate (high-high) municipalities, which totaled 39 municipalities, were located in the northern, northwestern, western and southwestern regions, and deserve more attention by municipal and regional managers to identify possible factors associated with pneumonia.

The kernel map (Figure 3) identified a greater density of municipalities with high rates (hot spots) in the northwestern and midwestern regions of the state.
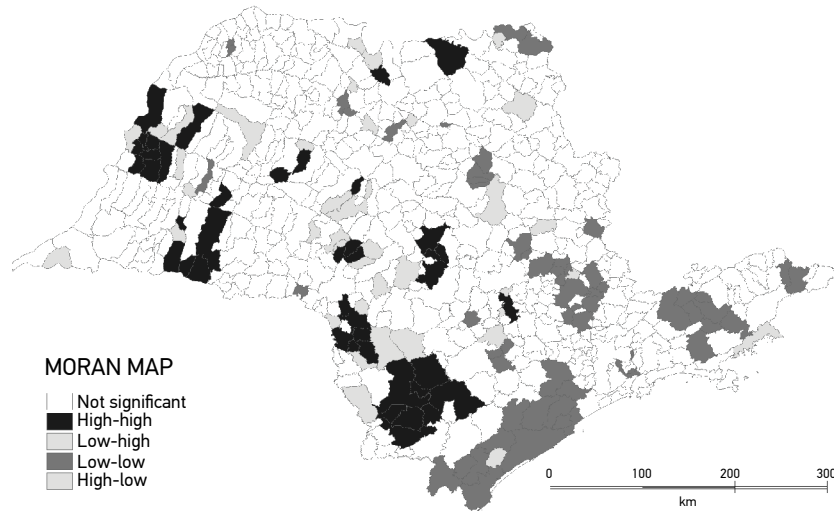

Figure 2. Moran map showing the 39 priority intervention areas, cities with high hospitalization rates for pneumonia surrounded by cities also with high rates (high-high). State of São Paulo, 2009 to 2013.
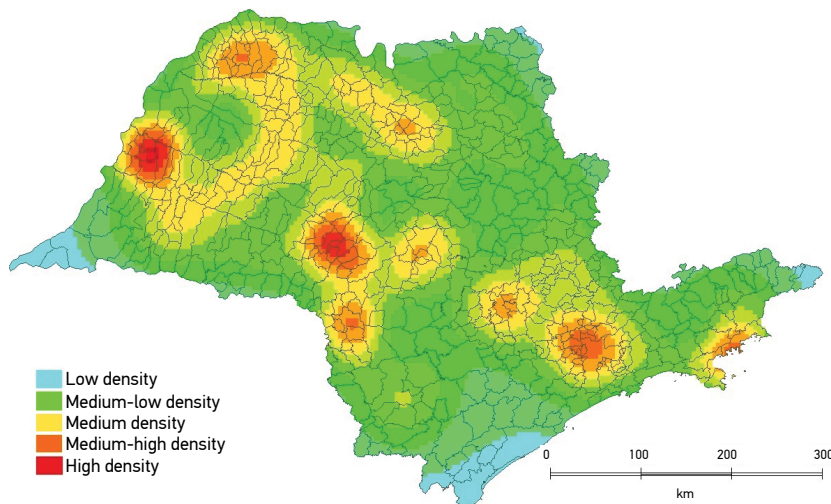

Figure 3. Kernel map showing the highest density regions for hospitalization rates for pneumonia. State of São Paulo, 2009 to 2013.

DISCUSSION

This study identified, using the Moran map, 39 municipalities in the state of São Paulo, located in the northern, northwestern, western and southwestern regions, with high pneumonia hospitalization rates for children under 4, which deserved special attention and possible intervention by regional and municipal managers. To the best of our knowledge, such a study is the first on hospitalization for pneumonia in children using the spatial approach, carried out with data from municipalities of the state of São Paulo, which makes it difficult to compare data obtained in the present work with data obtained in other studies on the subject, since they do not use the same approach and therefore have different advantages and limitations.

It was possible to observe a decrease in hospitalization rates for pneumonia in children in 2013 compared to 2009, possibly due to the introduction of pneumococcal vaccination. However, when we compared the mean hospitalization rates for pneumonia in children, city by city, in these two years, there are cities where these rates increased in 2013, data for which we have no explanation.

There is a correlation between hospitalization rates and the proportion of municipalities with residents whose family income is less than half the minimum. Both in the map regarding hospitalization and income, there are municipalities with high rates in the west and southwest of the state. There are, however, some disagreements; The hospitalization map identified municipalities with high rates in the north, northwest and center of the state, while the income map identified municipalities in the south and far east. Many factors, however, may be associated with these divergences, imposing some limitations on the study. Some of these factors may be the difficulty of access to health services for this portion of the population or the lack of information to alert families about signs of the disease, for example. In addition, the possibility of misdiagnosis leading to distorted records as well as the lack of information recording in certain cities is also considered. There is also the fact that often residents of poorer, and therefore less resourceful, regions seek health facilities in neighboring cities, providing addresses in this city of people in their relationship, causing an increase in the number of cases reported in these areas. poles, erroneously indicating cases in the city concerned. In some cases, children may be registered twice in case of readmissions.

Regarding the proportion of mothers with low education, there is also a positive association with the hospitalization rate, strongly evidenced in the north, northwest, midwest and southwest of the state, indicating that there is a correlation between the parameters and that there is a need policies should be established to provide this group with alert information on the issue, such as risk factors, signs and symptoms, basic care, etc. to minimize the number of cases. There are some cities in the south and far east of the state, however, that have low hospitalization rates despite high rates of low education; In these cases, we think again about the study's limiting factors already discussed.

When we analyzed Pearson's correlation between income below half a minimum wage and low maternal education, a positive correlation was identified between income below half a minimum wage and the number of hospitalizations. Other information is the significant correlation between the rate of hospitalizations in children for pneumonia and the proportions of mothers with low education.

When the hospitalization rate was analyzed by the Kernel estimator, there was a region with greater densification of municipalities with higher rates, in the northwest and midwest of the state, and these areas deserve special attention.

Although some differences have been found, several studies have shown, in different ways, the social determination of child mortality. A 1992 study found a positive association between low family income of children and their hospitalization, especially due to pneumonia[21]. Another study from 2001 found a positive association between low maternal education and child mortality[22].

An advantage of this study is the use of geoprocessing, which allows the integration of environmental data with health data, improving the characterization and quantification of exposure, its possible determinants and health problems. This methodology seeks to identify, in spatial structure and social relations, plausible associations with the processes of illness and death in communities. Cities are not isolated in space, they are interconnected with other larger or smaller urban centers and rural areas with which they establish exchange relations. The degree of connectivity and importance of a city, in general, has an effect on disease diffusion processes, that is, the most connected are reached more quickly.

Municipalities that rank in the high priority group should set the goal of lowering these rates to values of their medium- or low-priority neighbors. The proportion of hospitalizations for conditions sensitive to primary care has been used as a result marker of the quality of primary health care and as an indicator of access to outpatient care in the place in question[23] In this context, the results obtained in this study about the hospitalization rates and proportion of mothers with low education and low income families indicate the need for investment in primary care in the several municipalities identified with high intervention priority.

Ecological studies often have limitations. We can mention, among them, the fact that we worked with secondary data. In this study, the data source was DATASUS, the official source for accounting data analysis, but it contains information that can be used in ecological studies in Brazil. As already mentioned, there are errors in the diagnosis of hospitalization and diagnostic overestimation, incorrect provision of the hospitalized child's residence and the possibility of double counting of the same patient, since the system does not identify readmissions. It is important to highlight that the records refer to hospitalizations that occurred in the public health system, which makes the socioeconomic variable analyzed in the study also overestimated, since most SUS users are of the lower socioeconomic class, while higher-socioeconomic people look for private health systems, which explains lower hospitalization rates in the northwestern and southeastern parts of the state, as they are known to be richer regions.

Most risk factors have been studied in relation to pneumonia incidence and mortality; however, few studies are available on the occurrence of hospitalizations. Such lack of studies on the subject makes it difficult to adopt specific measures aimed at reducing the severity of cases and, consequently, reducing the contribution of this disease to childhood mortality rate[11].

CONCLUSION

Although with limitations, our study provides data for municipal and regional managers for in-depth research on the reasons that lead to higher hospitalization rates for children with pneumonia, thereby minimizing SUS expenses with hospitalizations for pneumonia in children up to 4 years old, in addition to the social cost that such hospitalizations entail.

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