Original article

Spatial analysis of intentional homicides in João Pessoa, Paraíba, Brazil, 2011-2016*

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Abstract

Objective: to describe spatial patterns of intentional homicides in João Pessoa, Paraíba, Brazil, 2011-2016. **Methods:** this was an ecological study using census tracts as units of analysis; the study used data on intentional homicides of victims living in João Pessoa obtained by cross-checking Mortality Information System (SIM) information with Public Security information; mortality coefficients were calculated for the whole period and its triennia and were later smoothed using the local empirical Bayesian method; spatial autocorrelation techniques were applied to the smoothed coefficients which were using Moran's spatial statistics. **Results:** significant spatial autocorrelation was detected for the period as a whole (I=0.679, p=0.01), the 1st triennium (I=0.508, p=0.01), and the 2nd triennium (I=0.572, p=0.01); areas of greater risk were identified distributed among the western, northwestern, southeastern, and far south zones of the city, mainly in regions with low socioeconomic conditions; census tracts with low coefficients were located in areas of medium/high socioeconomic status. **Conclusion:** homicides in João Pessoa were high in poor districts and these are priority areas for intervention.

Keywords: Homicide; Epidemiology; Mortality; Violence; Ecological Studies.

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Introduction

The occurrence of homicides, in particular intentional homicides, is of interest to Public Health, especially because of their links with a social structure that excludes: their occurrence increases as social inequalities worsen.[1,2]

In recent decades, the process of urbanization in developing countries has directed resources to the wealthiest areas of cities. The result of this option can be seen in the reduction of basic social rights to work, health, education, housing and urban infrastructure experienced by people living in city outskirts and impacting on their citizenship.[2] This situation creates privileged spaces of expression of social inequalities, where situations of violence are reproduced.[1-3]

Globally, homicides increased noticeably with effect from the second half of the 20th century.[4] In 2014, intentional homicides accounted for the deaths of almost half a million people worldwide, totaling a global average of 6.2 homicides per 100,000 inhabitants. It is estimated that 36% of these homicides occurred in the region of the Americas.[4] In the same period in Brazil, the consequences of the country's social inequality were reflected in the homicide mortality coefficient of 29.9 per 100,000 inhab., whereby the highest rate occurred in the Northeast region where there was a coefficient of 32.8 deaths per 100,000 inhabitants.[5,6]

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Latin America has the largest number of violent cities in the world, accounting for 42 out of the 50 most violent cities listed in 2016.[7] Seventeen of these cities are located in Brazil, with Natal-RN in the lead with 102.6 homicides per 100,000 inhab., followed by Fortaleza-CE (83.5 homicides/100,000 inhab.) and Belem-PA (71.4 homicides/100,000 inhab.). The 2016 study also reveals that violence has spread to smaller cities, in the wake of population migration to inner state regions, taking with them the dynamics of violence from large metropolitan regions to smaller areas where the presence of the State is not so strong.[1,5,7]

João Pessoa, capital of the state of Paraíba, has suffered the consequences of this process, in particular with regard to the overall trend of growth in the number of murders with effect from the 1990s. This city is in 29th position on the list cited above and is in 10th position among Brazilian cities, with a coefficient of 49.2 homicides per 100,000 inhabitants. However, due to the disorderly urbanization process mentioned above, it is to be expected that homicidal violence has not spread equally throughout the municipality of João Pessoa, given that considerable social inequalities exist between its different inhabited areas.[7-10]

The studies available on homicidal violence in Northeastern Brazil are usually confined to the main state capitals and address murders without going into intentionality. We did not find any studies in the indexed literature on death from intentional homicide and its spatial distribution in the municipality of João Pessoa. This study aimed to describe spatial patterns of intentional homicides in João Pessoa, Paraíba, Brazil, between 2011 and 2016.

Methods

This is an ecological study using census tracts such as geographical units of reference to investigate the spatial evolution of the distribution of the coefficient of mortality due to intentional homicide or murder in João Pessoa, Paraíba, between 2011 and 2016, and also in both of the triennia included in this period.

João Pessoa is officially divided into 64 neighborhoods, 963 census tracts and 5 Health Districts (Figure 1). The municipality has a per capita income of R$ 964.82, a Municipal Human Development Index (HDI-M) of 0.76 and a Gini index of 0.62.10 Neighborhoods located in the eastern and northeastern areas of the city, which correspond to its more central and coastal regions, are home to the largest number of families with higher per capita income, better quality of life, better HDI and lower social vulnerability, while those located in more peripheral areas (eastern, western, northwestern, and northern zones) are for the most part comprised of families with characteristics opposite to these.[10,11]

The study included all cases of intentional homicide the victims of which lived in João Pessoa between 2011 and 2016. Data on deaths owing to murder that occurred in the municipality during the study period were obtained from the Ministry of Health's Mortality

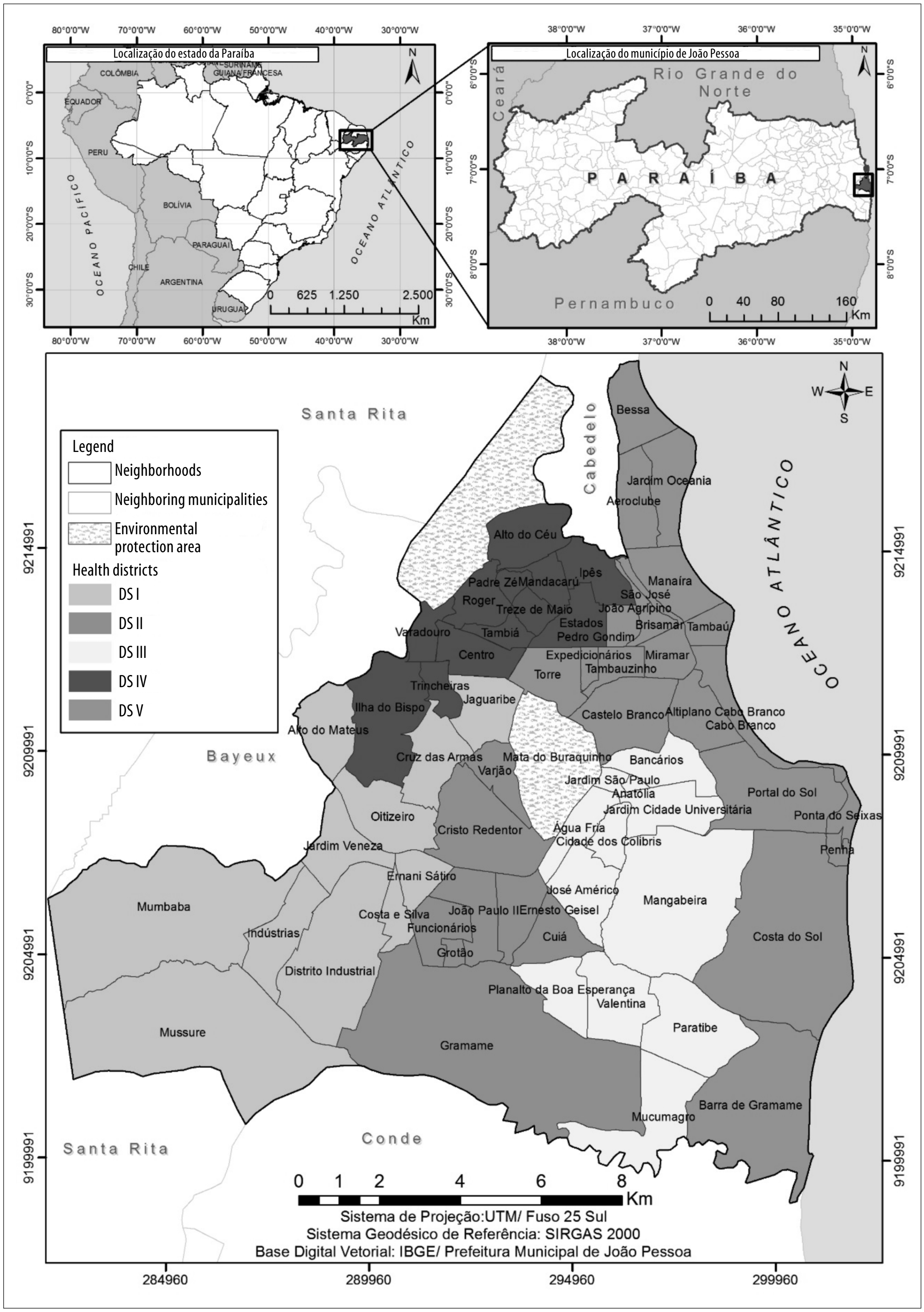


Figure 1 – Neighborhoods and health districts of the municipality of João Pessoa, Paraíba, Brazil

Information System (SIM). Murder was considered to be all deaths with underlying causes classified according to codes X85-Y09 and codes Y35-Y36 as per Chapter XX of the International Statistical Classification of Diseases and Related Health Problems (ICD - Tenth Revision (ICD-10).[12]

The variables 'year of occurrence of death', 'municipality of occurrence of death', 'victim's municipality of residence', 'resident population per census tract' and 'geographic latitude and longitude of death' were used to build the study's outcome variable, namely the mean coefficient of mortality from intentional homicide per census tract in the municipality of João Pessoa, Paraíba, in the period 2011-2016 and in the two corresponding triennia, 2011-2013 and 2014-2016.

In order to identify whether homicides were intentional and in order to obtain pairs of coordinates, the information held on SIM had to be cross checked with information held on Paraíba State Department of Social Security and Defense (SESDS/PB) database, by means of probabilistic database linkage using the RecLink application. To this end, we used a multiple step routine, whereby a given blocking key was used in each step.

First of all the two databases were standardized by removing duplicate records. The SIM database was used as the comparison file because this system holds more records than the SESDS/PB database.

The next stage consisted of database linkage using 18 steps to block and match records, comparing the blocks formed by matching the following variables: 'phonetic codes of the victim's first name and last name', 'sex of the victim', 'phonetic code of mother's first name' and 'age of the victim'. The comparison fields used were the victim's full name, age, mother's name and sex, the linkage parameters of which were estimated by applying expectation-maximization algorithms. These parameters were used to calculate the scores for the links formed in each blocking step.

Two new databases SIM and SESDS/PB databases were also created without the matches found to be true. A new matching strategy was applied to these databases using a new blocking key which was less specific than the previous blocking key. A unified file was generated, resulting from the matching process and containing the true matches identified by means of scores and manual review. Finally, we excluded victims who did not live in João Pessoa, thus generating the final database used in this study comprised only of records of intentional homicide of victims living in the municipality of João Pessoa.

The census tract population was taken to be that identified by the 2010 Demographic Census undertaken by the Brazilian Institute of Geography and Statistics (IBGE). The geographic coordinates were obtained from the database managed by SESDS/PB, which in turn was comprised of information from Military Police, Institute of Forensic Science and Civil Police databases. The event table was converted to Shapefile format.

The georeferenced information regarding the place of occurrence of an event involving a victim of intentional homicide was placed over the census tract mesh, thus enabling each data point to be linked to the corresponding census tract and enabling the generation of ecological information, while preserving the geographical location of occurrence of the murder.

Initially, we calculated the mean coefficient for mortality due to intentional homicides for the total period, using the average number of occurrences of homicides in the census tract, divided by the estimated population at the midpoint of each period and multiplied by 1,000. We chose to multiply by 1,000 inhabitants rather than 100,000 inhabitants because census tracts are small spatial units of analysis, with a low number of people at risk and a small number of murder cases. This also facilitated the reading and interpretation of the indicator. Following this, in order to check the evolution of the coefficient over time, we divided the study analysis period into two triennial periods.

To build the maps, we used the cartographic database of census tracts of the city of João Pessoa, in Shapefile format - using the geographic projection system (latitude/longitude) and the SIRGAS 2000 geodetic reference system -, retrieved from the IBGE website.

In order to avoid information bias, we cross-checked SIM database information with SESDS/PB database information to ensure that the deaths of people who did not live in João Pessoa were not included in the numerator when calculating the mortality coefficient.

The coefficients were smoothed using the local empirical Bayesian method, in view of random fluctuations found in the crude coefficients.[13,14] Thematic maps were then generated, categorized into quartiles, in order to be able to visualize the spatial distribution of the coefficients (crude and smoothed).

Following descriptive spatial analysis, an assessment was made as to global spatial autocorrelation of the mortality coefficients, which were smoothed for the total period and for the two triennial periods, by means of global Moran's analysis of spatial statistics. Moran's spatial statistics measure the correlation of a variable with itself in space, generating a value which varies from -1 to +1: values close to zero indicate spatial randomness; and positive and negative values demonstrate positive and negative spatial dependence, respectively.[15]

Once Moran's statistical significance ($p<0.05$) had been determined, the map was built based on the Local Indicator of Spatial Association (LISA) model, pointing out the areas with local correlation significantly discrepant from the rest of the data. We detected census tracts with high and low incidence and transition tracts by comparing the coefficient of each tract with the coefficients of the neighboring tracts, with the aim of finding spatial dependence as well identifying spatial clusters.[15] The clusters were categorized into four quadrants: Q1, high/high; Q2, low/low; Q3, high/low; and Q4, low/high. Q1 values indicated tracts with positive spatial correlation (positive values and positive means), while Q2 values indicated tracts with negative spatial correlation (negative values and negative means).[15]

Q3 values (positive values and negative means) and Q4 values (negative values and positive means) showed points with negative spatial association, i.e., when a tract has neighboring tracts with different values.[15] Moran maps were produced based on those census tracts with statistically significant differences ($p<0.05$). These procedures were carried out using the QGIS 2.18 and TerraView 4.2.2 applications.

This research project was approved by the Aggeu Magalhães Institute/Oswaldo Cruz Foundation Research Ethics Committee: Certification of Submission for Ethical Appraisal (CAAE) No. 66226517.1.0000.5190 and Opinion No 2.069.104, dated 17 May 2017.

Results

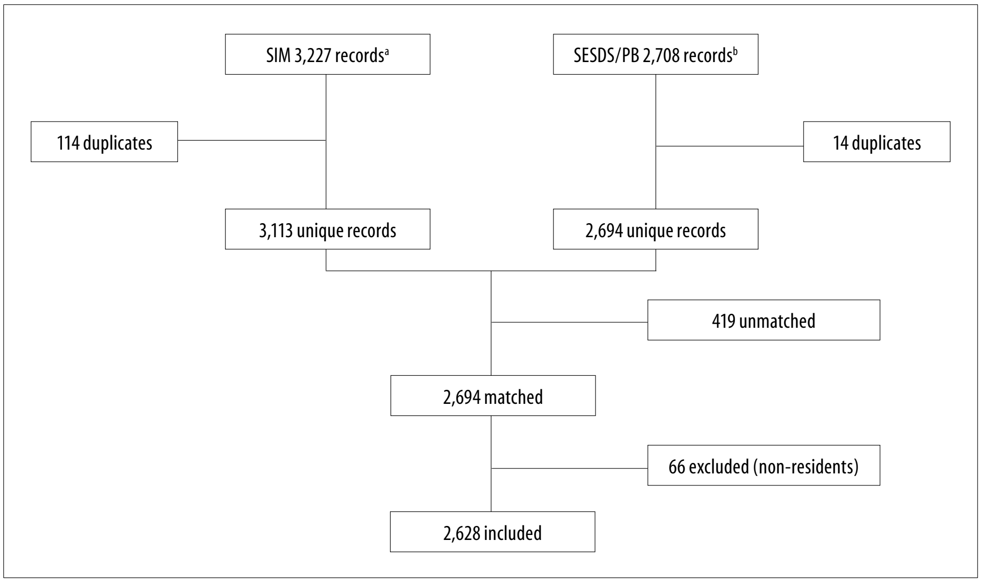
For the period 2011 to 2016, the SIM database initially contained 3,227 deaths due to homicide, whether intentional or not, of people resident and non-resident in João Pessoa, while the SESDS/PB database had 2,708 records of intentional homicide of people resident and non-resident in the municipality. During the standardization stage (removal of duplicates) of the linkage process, 114 records were removed from SIM and 14 from the SESDS/PB database because they were duplicated, resulting in 3,113 single cases in the SIM database and 2,694 in the SESDS/PB database. Following the database linkage stage, we excluded a further 419 records of unintentional deaths among residents and non-residents, resulting in a unified database of 2,694 records of deaths due to intentional murder of residents and non-residents. After excluding 66 cases corresponding to victims who were not resident in the city, the final database used had 2,628 records of georeferenced intentional homicides of victims who lived in the municipality of João Pessoa (Figure 2).

Of the total number of 963 census tracts, 689 (71%) were found to have homicides in the total study period. In the first triennium studied (2011-2013), 568 (59%) census tracts were found to have intentional violent deaths, while there were 497 tracts (52%) in the second triennium (2014-2016).

Analysis of the crude mortality coefficients found spatial autocorrelation for the total period ($I=0.137$; $p=0.01$), for the 1st triennium ($I=0.101$; $p=0.02$) and for the 2nd triennium ($I=0.127$; $p=0.02$). The comparison of the distribution of the crude and smoothed coefficients can be visualized in Figure 3 (A and B) and Figure 4 (A and B; D and E). The smoothed thematic maps showed that the highest 25% of mortality coefficients are distributed over the west, northwest, southeast and far south areas of the municipality, reaching the maximum value of 83 homicides per 1,000 inhabitants.

Moran's global index for the smoothed coefficients for the total period was 0.679 ($p=0.01$). The clusters of tracts with the highest mortality coefficients where neighboring tracts also had high rates (Q1) were concentrated mostly in economically deprived areas of the city (Figure 3, C). We observed the presence of tracts with high/low and low/low patterns. There were no clusters with a low/high pattern.

The smoothed maps referring to the 1st triennium showed that the highest 25% of mortality coefficients are distributed over the west, northeast, southeast and far south areas of the municipality (Figure 4, A and B), reaching maximum values of approximately 10 homicides per 1,000 inhabitants.



a)SIM: Mortality Information System.
b) SESDS/PB: Paraíba State Department of Social Security and Defense.

Figure 2 – Linkage process of the Mortality Information System database and the State Department of Social Security and Defense database, João Pessoa, Paraíba, 2011-2016

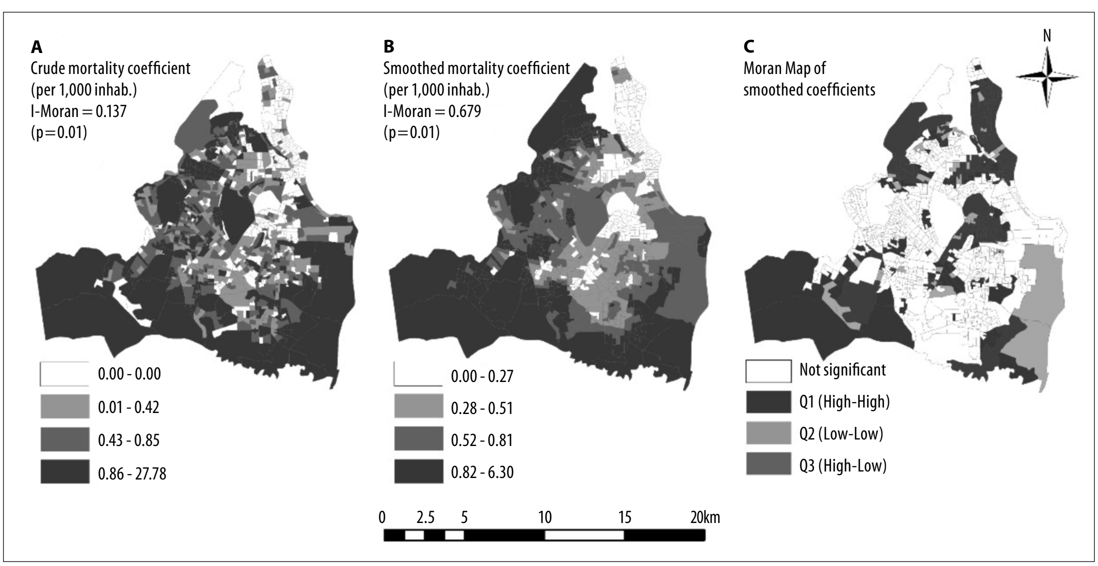


Figure 3 – Spatial analysis of the homicide mortality coefficient (per 1,000 inhabitants): crude coefficient by quartiles (A), smoothed coefficient by quartiles (B) and Moran's index (Moran Map, C), João Pessoa, Paraíba, 2011-2016

Moran's global index for the 1st triennium had a statistically significant positive value (I=0.508; p=0.01). We identified clusters of tracts with high mortality coefficients, where neighboring tracts also had high coefficients, situated in regions predominantly on the outskirts of the city, distributed over its north, northwest and southeast areas. Clusters of tracts with low/low and low/high patterns were identified in the central and eastern areas of the municipality (Figure 4, C). In

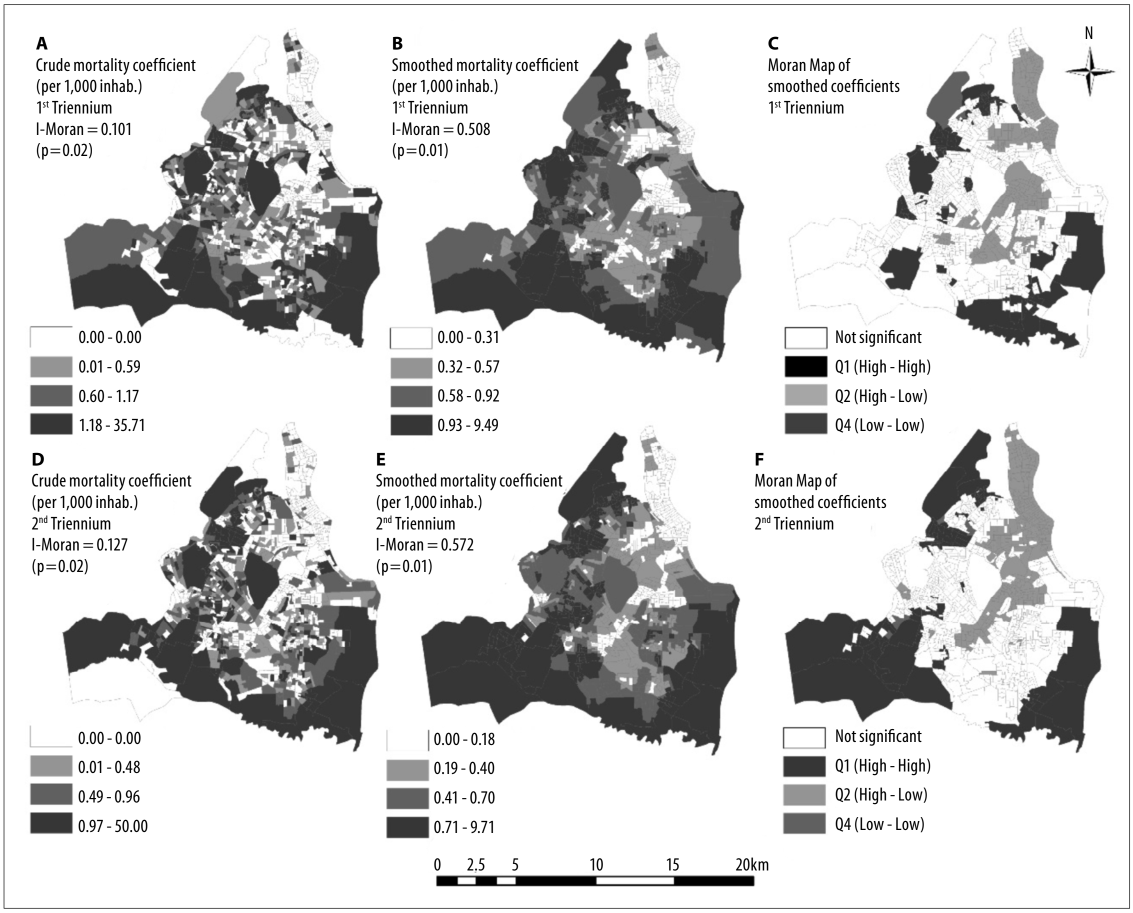


Figure 4 – Spatial analysis of the homicide mortality coefficient (per 1,000 inhabitants) in the 1st and 2nd triennia: crude coefficient by quartiles (A and D), smoothed coefficient by quartiles (B and E) and Moran's index (Moran Map, C and F), João Pessoa, Paraíba, 2011-2016

the first triennium there were no clusters with a high/low pattern.

With regard to the 2nd triennium (2014-2016), the smoothed map showed that 11 tracts had high mortality coefficient values and that neighboring tracts also had high coefficients. These tracts are distributed over the west, northwest, southeast and far south areas of the municipality (Figure 4, D and E), reaching maximum values of approximately 10 homicides per 1,000 inhabitants.

Moran's global index for the 2nd triennium showed spatial dependence (I=0.572; p=0.01). We identified three clusters of tracts with a high/high pattern distributed over the northwest, southwest and southeast areas of the municipality (Figure 4 F) with neighboring clusters of tracts with a low/high pattern.

Discussion

The areas with higher risk of occurrence of intentional homicides in João Pessoa coincide with regions known to be of greater social vulnerability. Differences were found between the two triennia with regard to the distribution of clusters with higher mortality coefficients with neighboring tracts also having high coefficients. In the first triennium these areas were located in the central/outskirts region of the city, while in the second triennium they moved and were concentrated in three outskirt regions characterized by disorderly urbanization caused by the agglomeration of poor people in regions close to environmental protection areas.[10] This movement towards the outskirts probably occurred because of the unequal distribution of State interventions, following the global trend of violent events, such as intentional homicides tending to occur in economically disadvantaged places.[2-4,16,18,19,23-29]

Although the data used in this study were retrieved from official information systems, they are subject to information bias, given the process that takes place between the occurrence of the event and the data being input on the systems. The first limitation of this study is underreporting which is reflected in the reduction in the number of deaths reported because of burials taking place without the required notification being made. Another problem is information completeness and consistency, given that the filling in of information about deaths, including deaths due to homicide, requires details of the circumstances of the event, such as the full address of the place where death occurred and the nature of death (homicide, suicide or accident), for example. This data comes from various sources, such as Public Security and Health services.[2,16,17]

In addition, although the SIM database provides information about the location of the occurrence of death, it provides no data on the place where the violent event that preceded death occurred. The SESDS/PB database overcomes this shortcoming by providing georeferenced information on this place. In this way we were able to avoid duplication of cases by place of occurrence of death which generally relates to the same address or neighborhood in which the reference hospital is located. Analysis using only SIM data would therefore not enable knowledge of the real situation of local intentional violence which is what we have studied here.[16,17]

The fact of homicides having occurred in areas of greater social vulnerability is corroborated when one considers intentional homicide, as is the case of our study. Intentional homicide has characteristics that are peculiar to it: the individual who commits this crime intends to kill and plans and carries out the murder. This behavior can be explained, in part, by the tendency of young people giving great importance to immediate rewards, associated with the lack of perspectives arising from social inequalities, leading them to commit violent acts.[2,16]

Another motivating factor for this type of crime can be related to the existence of family conflicts, this being a factor potentially capable of leading young people to the world of drugs, this being an environment that encourages criminal practices, such as the trafficking of narcotics. This type of economic activity gives young people a false sense of power and belonging, as well as providing easy money, encouraging them to commit, in addition to trafficking itself, crimes such as burglary and theft, as well as causing people to use drugs and become dependent on them, with the aim of generating profits and keeping the structure of organized crime under the control of drug traffickers.[2,16,19]

We took care in this study to include in the numerator used to calculate the mean mortality coefficient for intentional homicides in João Pessoa only victims residing in the city, given that only they are exposed to social risks occurring where they live. If the victims who were not part of this criterion, corresponding to 10% of the records, had been included in the final sample, this would have resulted in a misleading increase in the proportion of homicides, distorting local reproduction of this type of violence, given that this calculation would have included, for example, non-intentional homicides caused by traffic accidents or even by accidental triggering of firearms. The inclusion of murder victims who did not live in João Pessoa would also have encompassed crimes which, although intentional, are one-off and spontaneous, and would not have reproduced the interpersonal violence occurring in drug trafficking situations, for example.[5,7,12,17,30]

The quantitative maps aimed to present the spatial distribution of the crude and smoothed coefficients. The method of dividing classes by quantiles (quartiles) was the best way of revealing the complexity found in mortality coefficient distribution, when compared to other methods (equal intervals or natural breaks/Jenks, for example), contributing to a clearer visual perception of different socioeconomic conditions as close as possible to reality, of which maps are a simplified representation, as well as allowing comparisons.[15]

Analysis of the autocorrelation of the smoothed coefficients enabled the identification of clusters of risk of occurrence of intentional homicides and removed the influence of discrepant values. The resulting adjustment provided the indicator with greater stability, based on the coefficients of the neighboring tracts that comprised the area studied.[15,22]

This fact has practical implications, both for epidemiology and also for the management of public services. With regard to epidemiology, the usefulness of this graphical representation lies in the fact that it demonstrates, visually, the spatial patterns of risk of occurrence of intentional homicides, facilitating understanding of the event.[15,20,21] In addition to their epidemiological usefulness, these studies also corroborate the information produced by smoothed maps, by allowing visual observation and interpretation of the spatial pattern of events, thus contributing to more rational decision-making by the public sector.[23-25,27,28]

Actions can be planned in a more egalitarian manner, targeting human, material and technological resources to the most problematic areas, contributing to greater efficiency in the use of public resources.[20,21]

The usefulness of the Bayesian method associated with Moran's spatial statistics in assisting the identification of areas of risk of occurrence of diseases and events has been highlighted in other studies.[20,21] An ecological study conducted in the state of Tocantins between 2001 and 2012 with the aim of identifying areas of risk of occurrence of leprosy, used descriptive spatial analysis, the local empirical Bayesian method and analysis of spatial dependence, by means of Moran's global and local indices. The clusters formed based on smoothed coefficients on maps were found to be more suitable for the identification of areas with significantly higher risk of leprosy, allowing better visualization of the spatial pattern of the disease.[20] Another study conducted in the state of Minas Gerais in 2012, with the aim of identifying areas of risk for mortality from mouth and oropharyngeal neoplasms, compared crude and smoothed mortality coefficients and concluded that the application of the Bayesian method generated more stable corrected indicators.[21] Both studies[20,21] corroborate the findings of our study regarding the usefulness of these methods.

Given that the spatial distribution of homicides was not random and that there was a change in the spatial pattern of murders with effect from the 2nd triennium, we can deduce that the clusters of tracts with high coefficients, with neighboring tracts that also had high coefficients, were distributed in peripheral areas of the city. Historically, the southeast, southwest, northwest, and northern areas of João Pessoa have been associated with poverty[10] and, therefore, must be a priority target for intervention. The clusters with a low mortality coefficient and with neighboring tracts that also had low coefficients, are located in areas known to be of a middle/high socioeconomic level (the east and northeast areas of the city).

In this study it was also possible to identify, beyond areas of clusters with high risk of occurrence of intentional homicides, areas which although they are high risk, are surrounded by areas of low incidence which may be influenced by the neighboring high risk areas. These are the so-called areas of epidemiological transition[15] and for this reason they are considered to be medium priority areas by government programs focusing on prevention.

Moran's global index for the 1st and 2nd triennia pointed to positive spatial dependence, with similarity in mortality coefficients between the tracts where the clusters with high and low rate patterns were identified in areas similar to those found in the analysis of the total period. The absence of clusters in the western zone with high coefficients in the 2nd triennium, in relation to the 1st triennium, draws attention and indicates a reduction in occurrences possibly related to improvement in the coverage of municipal Public Security services in João Pessoa. A program intended to reduce homicides called 'Paraíba United for Peace' was deployed by the State in the year 2011 and is considered to be a crucial factor for achieving this reduction.[8] However, despite the significant reduction observed, there are areas of the municipality which continue to have high incidence cluster patterns and which require intensification of surveillance actions.

The distribution pattern of the occurrence of intentional homicides in João Pessoa points to a possible association with the growing and disorderly process of urbanization, and consequent expansion of urban problems, especially in the city's peripheral areas. In practice, social demands accumulate in a city where accelerated population growth is not accompanied by an equivalent expansion of urban services infrastructure. This process of urban growth may be responsible for the dichotomy between accumulation of wealth and poverty, favoring the spread of slums, and creates an environment in which the poorest youth from peripheral areas are more exposed to situations of unemployment and marginalization.[24,25,27]

An ecological study examined the association between socioeconomic and demographic factors and homicides in the general population of the state of Bahia in 2009. That study used Moran's global and local indexes to determine the existence of spatial clusters of occurrence of homicides. The study found that the process of disorderly urbanization, although it has lead to cities becoming larger and having better socioeconomic conditions, has contributed to increasing social inequality among the inhabitants of these places, resulting in increased homicide rates.[23] Another study conducted in Fortaleza in 2014, showed that homicide mortality was associated with high levels of poverty and uncontrolled urbanization.[27]

Research on the spatial pattern of homicides in the municipality of São Paulo reported as long ago as 1999 that the peripheral regions and the former center of the city where poverty indices are higher accounted for the largest number of homicides.[25] Another study on urban segregation and violence conducted in the municipality of Rio de Janeiro between 2002 and 2006, pointed to the existence of murder distribution patterns in the territory that reveal the deepening of social segregation of those living in highly-populated favelas and those living in the poorest neighborhoods.[24]

Although a reduction in the overall mortality coefficient for intentional homicides was found in the period analyzed, areas with high risk still persist, coinciding with places where poverty is high. These findings and their analysis can contribute to better planning and greater efficiency of control actions, strengthening and targeting violence prevention policies in these areas. In addition, we suggest that further studies be conducted to estimate the influence of other variables, such as social and economic determinants, on the occurrence of these homicides, and to verify access by the exposed population to public services such as schools, health centers and police stations. These are initiatives capable of producing more accurate information about the dynamics of these events.

Authors' contributions

Oliveira ALS and Luna CF participated in the design, planning, analysis, interpretation and writing the final version of the manuscript. Quinine LRM participated in the planning, analysis, interpretation, writing and revising the final version of the manuscript. Magalhães MAFM participated in data interpretation and in the critical revision of the article. Santana VCM participated in building the database and the final revision of the manuscript. All the authors have approved the final version and declared themselves to be responsible for all aspects of the study, ensuring its accuracy and completeness.

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