Spatial-temporal patterns and trends of homicide in socioeconomically deprived settings: violence surveillance in Alagoas, Brazil, 2006–2015

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Research

Keywords: Brazil, Homicide, Violence, Spatial-temporal analysis

DOI: https://doi.org/10.21203/rs.3.rs-55484/v1

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Abstract

Background

Homicide rates in the state of Alagoas (Brazil) have been high for a long time over the last decade. In this study, we quantified the violence rates and mapping the cities in higher risk for homicide.

Method:

A surveillance of homicide rates over ten years in the state of Alagoas, located in North-Eastern of Brazil was carried out through spatial-temporal analysis. First, the male/female ratio was calculated later the top violent cities and the relative risk for males and females were mapped.

Results

A total of 19,560 homicides were investigated in two large regions of the state called Metro Region and Inner Cities. A pattern of violence by homicide involving mostly men throughout all state was observed and highest rates for the metropolitan region of the state capital. Homicide has been spreading from the capital to other inner cities, and distinct pattern was observed when mapping the risk according to sex.

Conclusions

Homicide has remained as a serious local problem in the state over ten years, and our results suggest that inner areas in the state have experienced an increase of homicide rates, requiring strong investment in combat and prevention.

Background

Global estimates indicated that 477,000 homicides occurred in 2016 [1]. These intentional causes of deaths constitute a significant and avoidable burden to global health and to social-psychological wellbeing of communities worldwide. However, this burden is not equally distributed at global scale, with particularly elevated homicide rates observed in Latin America [2]. Concerns surrounding Brazil's hosting of the 2014 World Cup and 2016 Olympics brought international attention to the extreme degree to which violent crime occurs in Brazil; recent estimates from the Institute of Applied Economic Research (IPEA) indicated a clear upward trend since 2007, with homicide rate of 31.6 per 100,000 inhabitants in 2017 [3]. For comparison purposes, this is nearly 30 times the homicide rate in Germany or 158 times the homicide rate in Japan [4].

Homicide is generally defined as the intentional killing of another person, which may or may not be related to other criminal events. While each individual instance of homicide features unique circumstances, evidence from the literature traces upstream pathways which specifically highlight how adverse social and material conditions can aggravate a person's psychological state and make them more likely to attack another person [5]. In this way, homicide may be seen as reflecting adverse social, economic, and material contexts and their effects on the psychosocial health of individuals.

Given the relationship between socioeconomic contexts and homicide, similar geographical heterogeneity can be observed, such that homicides tend to cluster in socioeconomically-deprived areas at multiple scales. For example, the global distribution of homicide rates indicates concentrations in countries with high socioeconomic inequalities (e.g., Brazil, Colombia, El Salvador), as well as at national scales (e.g., state-level differences) and local scales (e.g., between cities and neighbourhoods) [6]. Accordingly, spatial-temporal approaches provide a useful means for quickly examining and visualising homicide trends and patterns in order to provide appropriate policy responses in affected areas.

This paper showed a spatial-temporal approach to understand “where” and “when” homicides occur. Our scenario is one of the poorest and socioeconomically deprived Brazilian states called Alagoas, located in North-Eastern Brazil. The state has historically showed homicide rates among the highest in the world, with estimated rate of 71.4 per 100,000 inhabitants in 2011 [7]. Throughout the last decade, Alagoas has consistently showed homicide rates over 50 per 100,000 inhabitants [7], requiring interventions to the forefront of state-and national-level debate.

We carried out a quantitative and geographical analysis of one decade of homicide deaths in the state, using data from the National Mortality Information System (SIM). In order to design and implement interventions, the spatial and temporal homicide patterns must be investigated, and how socioeconomic status correlates in the space. Accordingly, this study presents a detailed analysis of a Brazilian state, aiming to identify and characterise patterns in a state-level surveillance.

Methods

Study Area
The state of Alagoas, located in North-Eastern Brazil, comprises 102 cities, including the capital Maceió, with population of 1,013,643 inhabitants in 2015. Approximately the size of the US state of Massachusetts, Alagoas has population of 3.3 million inhabitants and the third highest population density in Brazil (approx. 112 persons per km$^2$) [8]. The state has poor social indicators such as the highest illiteracy rate of Brazil (17.2% of population) [9] and the second lowest per capita monthly income of Brazil [8].

Participants, Inclusion Data and Sources

Since 1975, the Brazilian Ministry of Health has monitored nationwide mortality through surveillance via SIM system [10]. In Brazil, data from external cause of death are reported in all states through Health Secretaries to the Ministry of Health; which information is stored and later disclosed via web system called DATASUS (IT Department). We accessed ten years of data (2006-2015) available from the Mortality Information System; the national database of external causes of death.

All available data from fatal victims of homicide were included and categorized according to codes from the most current version of the International Classification of Disease [11]. Homicides comprise X85-Y09 codes ("aggression"). Other external causes of deaths with unknown intent were excluded, such as transport accidents, suicides, falls, unintended or unexplained poisoning. Information was accessed via DATASUS using the following search filters: state; city of residence; ICD-10 group; death year; and sex of the victim.

Variables from Incident Data

Our primary variable of interest was the number of deaths related to homicide in each of the 102 cities of Alagoas state. One of them was excluded in the spatial analysis, called Jequiá da Praia, because it was recently founded in 2012, through the emancipation of São Miguel dos Campos. One homicide occurred at Jequiá da Praia, which was reclassified as occurring in São Miguel dos Campos. The health strategies of the local government divided the state into two large regions: metropolitan region, whose capital is Maceió, we called Metro Region; and the other inner regions, we called Inner Cities. The list of all cities that comprise the state, including the estimated population size, and estimated population of men and women are added as additional file [see Additional File 1] at the end of the manuscript. Three variables were included to describe difference patterns throughout the state: sex of the victim; city (Metro x Inner); and year of occurrence.

Temporal Analysis

First, the crude number of deaths by homicide was computed using the temporal unit of year, categorizing by sex of victims (male x female) and region (state; metro; and inner). After, the sex-specific crude homicide rate per 100,000 inhabitants was calculated for each city for every study year, based on census-derived population estimations from the Brazilian Institute of Geography and Statistics-IBGE [12]. The pooled 10-year crude homicide rates were computed using the 2010 sex-specific census populations. Homicide rates were divided by region and summarized by arithmetic mean.

Spatial Homicide Pattern

A three-year-period (1st period from 2006-2008; 2nd period 2009-2011; 3rd period from 2012-2014) were divided to investigate the behaviour of homicide rates over time. In order to improve the map visualization, only homicide rates over than 80 per 100,000 inhabitants were considered. All geographic data were analysed using the Brazilian standard SIRGAS 2000 polyconic projection in the ArcGIS package software (v.10.4).

To understand rate differences between men and women in space, the spatially-smoothed relative risk was computed using empirical local Bayes with a linear inverse-distance spatial weights matrix (maximum distance = 100 km). The maximum distance was selected using Ripley’s K and through visual interpretation of sensitivity analysis results by authors who reside in the study area. Empirical Bayes was selected as it provides a non-parametric smoothing method to improve relative risk estimates based on local mean homicide rates, which reduces variance due to the small numbers and non-normal/non-Poisson data and parameter distributions [13]. Total number of homicides; crude rates and relative risk were mapped using empirical local Bayes for both males and females. All mapping for male-female analysis was performed using GeoDA software (version 14.0).

Socioeconomic Data

The socioeconomic status of each city was verified using the income value from the last Brazilian Census carried out in 2010 [14], which was ranked and compared with the homicide status. The variable that best fit the socioeconomic setting was the income value. This variable is defined as the “mean monthly income of each city”. Comparison was included only for the second period (2009-2011) of the time series. This choice was adopted to avoid bias, once that the use of census information for extreme periods (1st and 3rd period) could not represent the reality for the income status. Results for all 102 cities including mean income and homicide rate are included at the end of the manuscript as additional file [see Additional file 2]. Basic linear regression was then conducted to estimate association between income and homicide rate in the study area, as well second regression using a log-transformed income variable. Model fit and diagnostics were heuristically assessed.

Ethical Statement

No ethical approvals were required at host institutions, as this study used exclusively publicly-available data with no risk of victim identification.
Results

Over the ten-year, 19,560 homicides were observed. The state-wide homicide rate from 2006 to 2015 was 60.4 per 100,000 inhabitants; 81.8 for the Metro Region and 46.5 for Inner Cities. Analysing the descriptive homicide information, male victims accounted for over 90.0%, regardless of region, as observed in Table 1.

Table 1 Here.

After correcting the number of deaths by the male/female population size, the mean homicide rate per 100,000 inhabitants was notably higher in the Metro Region. Males contributed most for this reality, as we can see that the rates over the period were always above 140 per 100,000 inhabitants. Female deaths by homicide had small value, usually less than 10 per 100,000 inhabitants. Table 2 display all rates over ten years of homicide in the state, as well as the mean for the period.

Table 2 Here.

Figure 1 shows the homicide evolution in the state in three periods and describes how space changes considering the top incidence of homicide.

Figure 1. Here. Mapping for the highest homicides rates (>80/100,000).

The geographical distributions of male and female homicides are similar in the state; however disproportionately high rates are observed in the eastern part of Alagoas, most notably around the state capital Maceió (Figure 2 and 3). The empirical Bayes relative risk estimates indicate that the highest risk for males is concentrated in the city of Pilar, while elevated risk for females is found in Pilar, Marechal Deodoro and Coité do Nóia. Low rates and relative risk estimates were observed for both male and female populations in the western half of Alagoas.

Figure 2. Here. Mapping for the empirical Bayes relative risk estimates in males.

Figure 3. Here. Mapping for the empirical Bayes relative risk estimates in females.

The socioeconomic analysis in Table 3 indicated positive correlation between income and crude homicide rate, with average increase of 10 homicides per 100,000 inhabitants for every increase of R$ 100 (R$ = Brazilian currency) in average income. Average income accounted for just over 30% of the variance in homicide rates in the study area. Model diagnostics indicated acceptable homoscedasticity and near-normality of residues. The model featuring log-transformed income values exhibited slightly higher normality of residues, and accounted for slightly less variance in homicide rates.

Table 3 Here.

Discussion

This study reported the advance of homicide violence in the socioeconomically deprived state of Alagoas, Brazil. Our analysis described a time-series of deaths related to homicide and their spatial distribution. To further examine spatial and temporal patterns, the rates of 102 cities in the state of Alagoas were calculated and divided into two key regional categories: metro region and inner cities.

The state of Alagoas is a non-war region and did not have civil conict; however, this small Brazilian region had an incredibly high homicide rates in the time period analysed. Our results estimated 19,560 homicides, which represents an average of 5.4 deaths per day. International comparisons have classified the state near to the top violent countries such as Honduras, El Salvador, Venezuela and Colombia [15]. In Brazil, the boom of homicides started in 1980s, related to the consolidation of crime organization and increase of poverty and urban misery [16]. The three first cited countries are in complete social-civil vulnerability, including civil war; on the other hand, Alagoas is a different context, so what could explain the explosion in homicide rates in this state?

The answer of the above question requires a careful observation at homicide rates around the state region, and two important findings could be verified. First, homicide rates in the Metro Region are almost twice that of Inner Cities over the whole series; second, the male/female comparison is totally different, as males are victims in approximately 9 out of 10 cases. The metropolitan area of the state comprises 13 cities located in the Middle-Eastern portion of the state and its population is one third of the total state population. Since 1999, homicide rates have increased in the Metropolitan Region and some factor are suggested to be related such as the easy and inexpensive access to rearms; drug trafficking in suburban areas; and social problems (rapid urban population explosion, income concentration, low schooling) [17]. It is noteworthy that in Brazil rearms, represent the main homicide mechanism.

The male predominance in all state regions is compatible with national results [18]. According the IPEA data [3], men were victims of homicides in 91.8% of cases between 2007 and 2017 in Brazil, and this victimization pattern is observed in all territory. Some factors could explain this masculinity of violence, first it is need to understand that most homicides are committed using rearms, usually introduced already in the childhood
as a symbol of male universe, and these firearms reinforce a sexist culture [19]. The pattern of male-female rates distribution was very similar in both Metro Region and Inner Cities.

Our mapping for the top homicide cities during three distinct periods shows that, in the first transition period, the highest rates shifted from the metropolitan area (Maceió and Pilar) to the South-Eastern coast (2009-2011), and then the second transition (2012-2014) was the movement of the highest rates to Inner Cities. It appears that the highest homicide rates have spread out from the surrounding areas of the capital to the inner region. This geographic transition of homicides has been called “internalization of violence”, which means that in the North-Eastern Brazil, during the past three decades, the dynamics of homicide has been moved over the space, affecting not only metropolitan areas but also inner cities [20,21].

When mapping the relative risk of homicide considering the difference of territorial size, it was observed that homicide rates involving men is concentrated in the city of Pilar. This small territory had 33,305 inhabitants in 2010 and is located at west of the state capital. The main hypothesis to explain the historically homicides of men in this region is the dispute of drug traffic dominance between two criminal factions [22]. It is not easy to obtain information about criminal activity but two major factions have grown in the state, namely: “First Capital Command-PCC” (free translation) and “Red Command-CV” (free translation). The first emerged in 1993 in the São Paulo prison system and now has activities in almost all Brazilian states [23]; the latter emerged in Rio de Janeiro and had activities including connection with Colombia by the FARC [24].

The female mapping for relative risk was different from that for males and showed a clustered region for three cities: Pilar, Marechal Deodoro and Coité do Nóia. The first and second are neighbouring areas with similar characteristics including population and size. The latter is a very small area around a large city called Arapiraca in the middle region of the state. Femicide is often perpetrated by men that use physical power to subdue and humiliate the women, usually associated, but not exclusively, with intimate partner such as husband; boyfriend; lover; and ex-partner [25-27]. More recently, the discussion about female has used the Diana Russell’s definition of femicide including the killing of females by males because they are females, motivated by hatred, contempt, pleasure or sense of ownership [27,28].

The three cities with increased risk for female homicides are located close to large urban areas (Maceió or Arapiraca). This is possible related to some local factors; the further away from the metropolis the greater inequality, worst general living conditions, worst family income, less policing, growth of social inequality and greater involvement of young people in crime.

Alagoas and its neighbouring state Pernambuco had historically registered high femicide rates comparing to national data. While the Brazilian rate in 2013 was around 4.6 per 100,000 inhabitants [7], in this same year, Alagoas showed rate around 8.4 per 100,000 inhabitants. In the present investigation, the femicide peak was during 2010-2013, and this was coincident with the most violent years for males in the state. The female rate was also greater comparing to the North-Eastern state, which mean was 5.6 per 100,000 inhabitants in 2013 [29].

The increase in monthly income was coincident with increased homicide rates. This can be explained by the fact that the capital and the metropolitan region are the wealthiest in the state and also concentrate the highest homicide rates. Income data should be carefully examined, once in Brazil, rich and poor areas coexist in very close areas, which can obfuscate the poverty in some regions by using the average as parameter.

Political efforts to reduce homicide in Brazil started more effectively when in 2003, the Law 10,826 [30] was approved during Lula government, which increased the stringency for firearm possession, which could be reflected in decreased rates from 2003 to 2006 [31]. However, from 2007, homicide increased again and the last national estimation clearly showed a trend of increasing violence from 2007 to 2017 [3]. In 2019, President Jair Bolsonaro tried a series of Decrees to increase gun possession; however, they were denied by Senate and Supreme Court. In June 25, the government managed to approved Decree 9,847 [32] that expanded the power of weapons for ordinary people and authorizes shooting classes for adolescents.

Other Brazilian efforts to reduce homicide and prevent violence against women were Law No. 11,340 of 2006 [33], which created mechanisms to curb domestic and family violence against woman; Law No. 13,104 of 2015 [34], which included femicide in the Penal Code, extending the penalty when involving domestic/family violence or disparagement or discrimination against women, and Law No. 12,845 of 2013 [35], which determines that all woman victim of violence should have mandatory and comprehensive care in all Public Brazilian Hospitals.

In Alagoas, the reduction of 16.7% homicide rates was observed from 2014 to 2015 in our study. Estimated homicide rates from 2016 onwards can be accessed in the IPEA document; however, IBGE only provided the population of cities by sex until 2015 using the RIPSA estimation. This limitation affects the analysis of more recent years, in addition to the fact that the 2020 Brazilian Census will be possibly affected by the Covid-19 pandemic. It is possible that from 2015, the state of Alagoas experienced a novel homicide pattern, considering the sharp fall in rates in that year.

This homicide reduction in 2015 is coincident with the new state government that put into its agenda the strengthening of public security. The governor explained that this reduction reflects more investment, including: acquisition of armaments; technology; police vehicles; integrated centre of military and civil police; and better working conditions for police officers [36]. We must consider that the reduction in violence in recent years should be scientifically examined to avoid conflict of interest during dissemination of violence data. This could be an interesting new area to explore, unless we had the estimation population by sex, that will be possibly available with the new Brazilian Census.

Conclusions
In one decade, the homicide rate in the Brazilian State of Alagoas was incredibly high, with a clear pattern of male victimization and concentration in the metropolitan area. We could describe a phenomenon called "internalization of violence", considering the top violent cities of the state. Our spatial-temporal analysis around two large urban areas called Metro Region and Inner Cities showed distinct patterns for males and females. While male victims were concentrated around the state capital, the female pattern were distributed around three inner cities.

**Abbreviations**

ICD: International Classification of Disease; IPEA: Institute of Applied Economic Research; DATASUS (IT Department); SIM: Mortality Information System

**Declarations**

**Ethics approval and consent to participate**

The current research was performed using secondary data accessed via DATASUS (IT Department of the Government), last access on December 08, 2019. Information stored in DATASUS is free and open to researchers. Data accessed are grouped by city and did not represent individual victims; therefore, there is no need for ethics approval. The following website was accessed: [http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sim/cnv/ext10AL.def](http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sim/cnv/ext10AL.def)

**Consent for publication**

Not applicable.

**Availability of data and materials**

The datasets generated and/or analysed during the current study are available in the DATASUS website [http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sim/cnv/ext10AL.def](http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sim/cnv/ext10AL.def).

**Competing interest**

The authors declare no conflicts of interest during the conduction of the study and elaboration of the manuscript.

**Funding**

The present study received funding from Brazilian Ministry of Science, Technology, Innovations and Communication (MCTIC) and Nation Council for Scientific and Technological Development (CNPq) [Universal Notice MCTIC/CNPq n.28/2018].

**Authors’ contributions**

KG provided the initial idea/design of the spatial-temporal analysis, participated in DATASUS data acquisition, interpreted results and drafted the work. BW generated the formal analysis for the geographical and map elaboration. AS and GG participated in DATASUS data acquisition and interpretation of the study. EB and MR provided substantial contribution to the homicide design and interpretation. All authors approved the submitted version and agreed to be responsible for any part of the manuscript.

**Acknowledgments**

Not applicable.

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Tables

Table 1 Crude number of deaths according the region and the sex of victims

| Time Series | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|-------------|------|------|------|------|------|------|------|------|------|------|
| **Homicides** | **State** | 1618 (100.0%) | 1826 (100.0%) | 1887 (100.0%) | 1873 (100.0%) | 2087 (100.0%) | 2243 (100.0%) | 2046 (100.0%) | 2148 (100.0%) | 2085 (100.0%) | 1747 (100.0%) |
| | **male** | 1512 (93.4%) | 1718 (94.1%) | 1804 (95.6%) | 1762 (94.1%) | 1950 (93.4%) | 2105 (93.8%) | 1913 (93.5%) | 2005 (93.3%) | 1960 (94.0%) | 1652 (94.6%) |
| | **female** | 106 (6.6%) | 108 (5.9%) | 82 (4.4%) | 111 (5.9%) | 137 (6.6%) | 139 (6.2%) | 133 (6.5%) | 142 (6.6%) | 125 (6.0%) | 95 (5.4%) |
| **Metro Region** | 956 (100.0%) | 1031 (100.0%) | 1124 (100.0%) | 989 (100.0%) | 1134 (100.0%) | 1194 (100.0%) | 1057 (100.0%) | 1159 (100.0%) | 1000 (100.0%) | 765 (100.0%) |
| | **male** | 908 (95.0%) | 989 (95.9%) | 1078 (95.9%) | 939 (94.9%) | 1065 (93.9%) | 1124 (94.1%) | 990 (93.7%) | 1092 (94.2%) | 940 (94.0%) | 714 (93.3%) |
| | **female** | 48 (5.0%) | 42 (4.1%) | 46 (4.1%) | 50 (5.1%) | 69 (6.1%) | 70 (5.9%) | 67 (6.3%) | 66 (5.7%) | 60 (6.0%) | 51 (6.7%) |
| **Inner Cities** | 662 (100.0%) | 795 (100.0%) | 763 (100.0%) | 884 (100.0%) | 953 (100.0%) | 1049 (100.0%) | 989 (100.0%) | 989 (100.0%) | 1085 (100.0%) | 982 (100.0%) |
| | **male** | 604 (91.2%) | 729 (91.7%) | 726 (95.2%) | 823 (93.1%) | 885 (92.9%) | 981 (93.5%) | 923 (93.3%) | 913 (92.3%) | 1020 (94.0%) | 938 (95.5%) |
| | **female** | 58 (8.8%) | 66 (8.3%) | 36 (4.7%) | 61 (6.9%) | 68 (7.1%) | 69 (6.6%) | 66 (6.7%) | 76 (7.7%) | 65 (6.0%) | 44 (4.5%) |

Table 2 Homicides rates in the state according to sex

| RATES per 100 000 inhabitants |
|-------------------------------|
| **State** | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Homicides | State | 51.9 | 58.0 | 59.4 | 58.4 | 64.6 | 68.9 | 62.4 | 65.1 | 62.8 | 52.3 | 60.4 |
| | male | 98.7 | 110.2 | 115.7 | 112.1 | 123.2 | 132.2 | 119.4 | 124.5 | 121.1 | 101.6 | 115.9 |
| | female | 6.7 | 6.7 | 5.1 | 6.8 | 8.3 | 8.4 | 7.9 | 8.4 | 7.3 | 5.8 | 7.1 |
| **Metro Region** | 79.3 | 84.2 | 90.6 | 78.7 | 89.2 | 92.9 | 81.4 | 88.5 | 75.7 | 57.4 | 81.8 |
| | male | 156.2 | 165.7 | 180.6 | 155.5 | 174.7 | 182.6 | 159.5 | 174.6 | 149.2 | 112.6 | 161.1 |
| | female | 7.7 | 6.6 | 7.1 | 7.7 | 10.4 | 10.5 | 9.9 | 9.6 | 8.7 | 8.0 | 8.6 |
| **Inner Cities** | 34.6 | 41.3 | 39.4 | 45.3 | 48.6 | 53.2 | 49.9 | 49.7 | 54.3 | 48.9 | 46.5 |
| | male | 63.5 | 75.7 | 75.4 | 85.0 | 91.0 | 100.4 | 94.1 | 92.7 | 103.2 | 94.6 | 87.6 |
| | female | 6.0 | 6.8 | 3.7 | 6.2 | 6.9 | 6.9 | 6.6 | 7.6 | 6.4 | 4.4 | 6.2 |

Table 3 Model results indicating positive correlation between income and homicide
Figures

> 80 deaths by homicide per 100 000 population

2006-2008

2009-2011

2012-2014

Figure 1

Here. Mapping for the highest homicides rates (>80/100,000).
Figure 2

Here. Mapping for the empirical Bayes relative risk estimates in males.

Figure 3

Here. Mapping for the empirical Bayes relative risk estimates in females.
Here. Mapping for the empirical Bayes relative risk estimates in males.

**Supplementary Files**

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile2.docx
- Additionalfile1.docx