PUBLICAÇÃO OFICIAL DO NÚCLEO HOSPITALAR DE EPIDEMIOLOGIA DO HOSPITAL SANTA CRUZ E PROGRAMA DE PÓS GRADUAÇÃO EM PROMOÇÃO DA SAÚDE - DEPARTAMENTO DE BIOLOGIA E FARMÁCIA DA UNISC

Revista de Epidemiologia e Controle de Infecção

Hospital Santa Cruz

ORIGINAL ARTICLE

HIV/AIDS cases and deaths in Brazil, 2000 to 2019: a spatial analysis

Casos e óbitos de HIV/AIDS no Brasil, 2000 a 2019: uma análise espacial

Casos y muertes por VIH/SIDA en Brasil, 2000 a 2019: un análisis espacial

https://doi.org/10.17058/reci.v14i4.19319

Received: *04/13/2024*
Accepted: *10/21/2024*
Available online: *12/18/2024*

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ABSTRACT

Justification and Objectives: although there has been progress in antiretroviral treatment and advances in preventive campaigns, cases and deaths from HIV/AIDS persist today, reflecting a serious public health concern. This study aimed to carry out a spatial analysis of cases and deaths due to HIV/AIDS in Brazil, 2000-2019. **Methods:** this is a cross-sectional, ecological study. The data were extracted from the Notifiable Diseases Information System and the Mortality Information System. To identify spatial distribution patterns and possible clusters, Kernel maps and Local and Global Moran's Index of prevalence and mortality were created in TerraView and QGIS. **Results:** during the period of this study, there were 756,586 cases and 232,892 deaths from HIV/AIDS, with the highest concentrations of cases in the states of São Paulo and Rio de Janeiro and deaths in Rio Grande do Sul and Rio de Janeiro. In Kernel, there was high density in the Southeast, South and Northeast, mainly in Rio Grande do Sul, Rio de Janeiro and Santa Catarina, for the mortality rate. Meanwhile, in Local Moran's Index, high-value clusters are in the Southeast, South and Midwest, which are also the locations for the mortality rate. **Conclusion:** cases were concentrated in the state of São Paulo and Rio de Janeiro, while mortality rates reached higher density in Rio Grande do Sul and Rio de Janeiro. These findings point to the need for regional coping strategies, such as strengthening educational and prevention campaigns.

Keywords: *HIV. Acquired Immunodeficiency Syndrome. Public Health. Ecological Studies. Spatial Analysis.*

RESUMO

Justificativa e Objetivos: embora houvesse evolução no tratamento com antirretrovirais e avanços nas campanhas preventivas, os casos e mortes de HIV/AIDS hodiernamente persistem, refletindo-se em um grave problema de saúde pública. O objetivo deste estudo é realizar uma análise espacial dos casos e óbitos por HIV/AIDS no Brasil, 2000-2019. Métodos: trata-se de estudo transversal, ecológico. Os dados foram extraídos do Sistema de Informação

de Agravos de Notificação e do Sistema de Informação de Mortalidade. Para identificar padrões de distribuição espacial e possíveis clusters, realizaram-se mapas de Kernel e Índices Local e Global de Moran da prevalência e mortalidade no *TerraView* e QGIS. **Resultados:** no período deste estudo, ocorreram 756.586 casos e 232.892 óbitos de HIV/AIDS, com maiores concentrações dos casos nos estados de São Paulo e Rio de Janeiro e óbitos em Rio Grande do Sul e Rio de Janeiro. No Kernel, verificou-se alta densidade no Sudeste, Sul e Nordeste, principalmente no Rio Grande do Sul, Rio de Janeiro e Santa Catarina, para a taxa de mortalidade. Enquanto isso, no Índice Local de Moran, *clusters* de alto valor estão no Sudeste, Sul e Centro-Oeste, sendo estes também os locais para a taxa de mortalidade. **Conclusão:** os casos se concentraram no estado de São Paulo e Rio de Janeiro, enquanto as taxas de mortalidade atingiram maior densidade no Rio Grande do Sul e Rio de Janeiro. Essas descobertas apontam para a necessidade de estratégias regionais de enfrentamento, como o fortalecimento de campanhas educativas e de prevenção.

Descritores: *HIV. Síndrome da Imunodeficiência Adquirida. Saúde Pública. Estudos Ecológicos. Análise Espacial.*

RESUMEN

Justificación y Objetivos: si bien ha habido avances en el tratamiento antirretroviral y avances en las campañas preventivas, hoy persisten casos y muertes por VIH/SIDA, lo que refleja un grave problema de salud pública. El objetivo de este estudio es realizar un análisis espacial de los casos y muertes por VIH/SIDA en Brasil, 2000-2019. **Métodos:** se trata de un estudio ecológico transversal. Los datos fueron extraídos del Sistema de Información de Enfermedades de Declaración Obligatoria y del Sistema de Información de Mortalidad. Para identificar patrones de distribución espacial y posibles grupos, se crearon mapas Kernel y los Índices Local y Global de Moran de prevalencia y mortalidad en *TerraView* y QGIS. **Resultados:** durante el período de este estudio, hubo 756.586 casos y 232.892 muertes por VIH/SIDA, con las mayores concentraciones de casos en los estados de São Paulo y Río de Janeiro y de muertes en Rio Grande do Sul y Río de Janeiro. En Kernel, hubo alta densidad en el Sudeste, Sur y Nordeste, principalmente en Rio Grande do Sul, Rio de Janeiro y Santa Catarina para la tasa de mortalidad. Mientras tanto, en el Índice Local de Moran, los conglomerados de alto valor se encuentran en el Sudeste, Sur y Centro-Oeste, que también son las ubicaciones de la tasa de mortalidad. **Conclusión:** los casos se concentraron en los estados de São Paulo y Río de Janeiro, mientras que las tasas de mortalidad alcanzaron mayor densidad en Rio Grande do Sul y Río de Janeiro. Estos hallazgos apuntan a la necesidad de estrategias regionales para afrontar la situación, como el fortalecimiento de campañas educativas y de prevención.

Palabras Clave: *VIH. Síndrome de Inmunodeficiencia Adquirida. Salud Pública. Estudios Ecológicos. Análisis Espacial.*

INTRODUCTION

Acquired Immunodeficiency Syndrome (AIDS) is a disease caused by the Human Immunodeficiency Virus type 1 (HIV-1), which affects the immune system, attacking and destroying CD4+ T cells, which can result in serious complications.[1]

AIDS has already affected millions of people worldwide, with 1.3 million cases of infection and 690,000 deaths in 2023. Global estimates indicate that around 39 million people live with HIV worldwide, presenting a serious public health concern.[2] In Brazil, since the beginning of its spread until 2023, 1,124,063 cases of AIDS have been identified.[3]

The pattern of spread and mortality of HIV/AIDS can be instigated by sociodemographic differences, social inequality, health determinants and conditions[4]. Thus, it is known that the social determinants of health can influence the regional distribution of AIDS and the quality and expectancy of life through access to diagnosis, treatment and quality of life of people living with HIV/AIDS.[4] From this perspective, public actions and policies must consider local realities, profile and sociocultural characteristics of communities.[5]

Since the first signs of this HIV-1 pandemic, many actions, such as campaigns to prevent vertical transmission, development of antiretroviral therapies (ART), studies and political decisions, such as the free distribution of medications and the introduction of pre-exposure prophylaxis (PrEP) and post-exposure prophylaxis (PEP), have been taken to reverse and advance infected individuals' quality of life.[6] As it is considered a chronic disease, it requires greater attention from the population and healthcare professionals, requiring actions to stop its expansion.[7]

Currently, there is significant ART coverage among underdeveloped countries, accounting for 50% of people treated for the virus[8]. Brazil is considered an exception, as it is one of the few countries that provides free distribution of antiretrovirals[3]. ART has leveraged benefits in reducing AIDS morbidity and mortality and associated comorbidities, providing a better quality of life for people with HIV/AIDS. Moreover, PEP and PrEP are effective developments in the treatment, care and prevention of infection available in the Brazilian Health System (In Portuguese, *Sistema Único de Saúde* - SUS).[9]

HIV-1 causes several harms to the population, such as compromising the human immune system, increasing

vulnerability to opportunistic infections, and facing social stigma. The virus also has a high morbidity and mortality rate, affecting the population's workforce, with direct and indirect impacts that compromise productivity and social and economic well-being as well as overloading healthcare services.[4]

Spatial analysis tools are capable of identifying, delimiting and locating areas at risk for HIV/AIDS transmission and the occurrence of this disease, providing support for decision-making regarding control and reduction of harm to the population at risk.[10]

Given this context, this research is justified by the hypothesis that, although there has been progress in ART and advances in preventive campaigns, cases and deaths persist to this day, reflecting a serious public health concern in Brazil, making it necessary to identify which are the priority areas for greater interventions in relation to HIV/AIDS. This study aimed to carry out a spatial analysis of HIV/AIDS cases and deaths in Brazil from 2000-2019.

METHODS

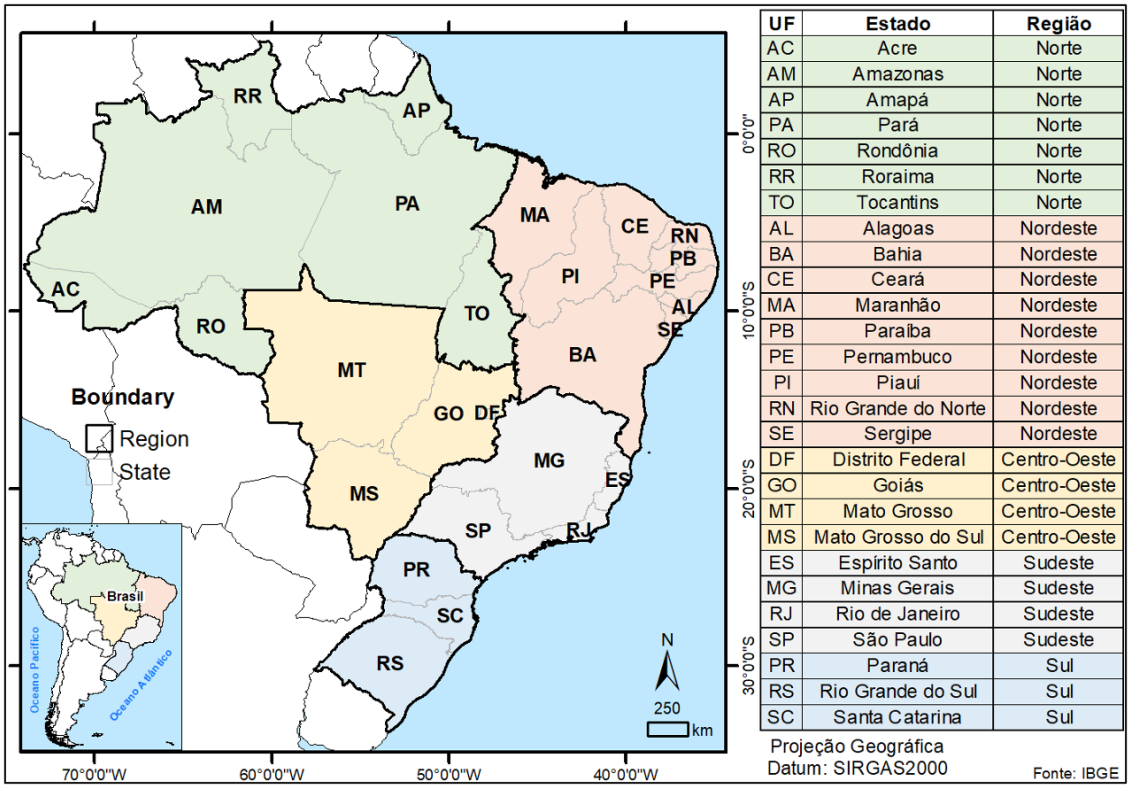
This is an ecological study in Brazil, based on all confirmed cases in the Notifiable Diseases Information System (In Portuguese, *Sistema de Informação de Agravos de Notificação* - SINAN) and deaths from HIV/AIDS registered in the Mortality Information System (In Portuguese, *Sistema de Informação sobre Mortalidade* - SIM), from 2000 to 2019, according to the state. Access was via TabNet, available on the DATASUS platform (https://datasus.saude. gov.br/), accessed on December 10, 2020.

Brazil is located in South America, with a territorial area of 8,516,000 km^2, administratively divided into 5,570 municipalities, 26 states and the Federal District, and five geographic regions (North, Northeast, Southeast, South and Midwest) (Figure 1), with a population of 203,062,512 million inhabitants, a Human Development Index of 0.754 and a Gini of 0.491.[11]

The variables used for confirmed cases were year of diagnosis, region, and state, and for deaths, they were year of registration, region, state, and death by residence. The prevalence and mortality rates were calculated for the total period and by decade. For prevalence, the number of confirmed cases was divided by the population, multiplied by 100,000 inhabitants. Mortality was calculated based on the ratio of the number of deaths to the population, multiplied by 100,000 inhabitants. The data related to the population are based on population estimates for each year carried out by the Brazilian Institute of Geography and Statistics.

For the spatialization of HIV/AIDS epidemiological indicators in Brazil, analyses were performed by geographic region, state and municipality. Maps of total case distribution, Kernel, Local and Global Moran maps were created by grouping points of case prevalence and mortality rate.

Kernel density was used as an alternative for analyzing the behavior of rate density patterns. Adaptive ray was used because it corresponds to a statistical method in which, through the interpolation of point



UF	Estado	Região
AC	Acre	Norte
AM	Amazonas	Norte
AP	Amapá	Norte
PA	Pará	Norte
RO	Rondônia	Norte
RR	Roraima	Norte
TO	Tocantins	Norte
AL	Alagoas	Nordeste
BA	Bahia	Nordeste
CE	Ceará	Nordeste
MA	Maranhão	Nordeste
PB	Paraíba	Nordeste
PE	Pernambuco	Nordeste
PI	Piauí	Nordeste
RN	Rio Grande do Norte	Nordeste
SE	Sergipe	Nordeste
DF	Distrito Federal	Centro-Oeste
GO	Goiás	Centro-Oeste
MT	Mato Grosso	Centro-Oeste
MS	Mato Grosso do Sul	Centro-Oeste
ES	Espírito Santo	Sudeste
MG	Minas Gerais	Sudeste
RJ	Rio de Janeiro	Sudeste
SP	São Paulo	Sudeste
PR	Paraná	Sul
RS	Rio Grande do Sul	Sul
SC	Santa Catarina	Sul

Figure 1. Map of Brazil according to the 26 states, including the Federal District, and the five geographic regions.

data per unit area, a smoothly curved density surface can be modeled, adjusted over each analyzed point with higher surface values at its location, which decrease with increasing distance from the point, obtained through the Silverman equation:[12]

$$\hat{f}(x) = \frac{1}{nh^2} \sum_{i=1}^{n} K\left\{\frac{x - X_i}{h}\right\}$$

Where:
x = coordinate vector of observed point;
n = total points analyzed;
h = bandwidth;
K = Kernel function;
X_i = vector of i-th coordinate of each point existing in the neighborhood of observed point.

In addition to the density study, the investigation of data spatial autocorrelation is proposed. This resource analyzes the degree of dependence between the values observed in the study area, i.e., it estimates how much the value of an attribute in a region is dependent on the values of that same attribute in the neighborhood.[13] To verify spatial autocorrelation, Global and Local Moran's Indices were calculated.

Global Moran's Index is widely used to indicate the existence of spatial autocorrelation in a data set. It is a normalized index in which attribute values are subtracted from their mean and divided by standard deviation, which is based on an initial null hypothesis that there is no spatial dependence. Its values vary within a range of -1 to +1, with the closer to +1, the stronger the spatial dependence, indicating similarity between the attribute value and its surroundings. Values equal to or very close to 0 indicate that there is no spatial autocorrelation and that the aforementioned null hypothesis is true. Negative values are rarely obtained, but when they do occur, they indicate areas with negative autocorrelation.[14,15]

Local Moran's Index was applied to identify areas of confluence of confirmed HIV/AIDS cases, consisting of municipalities that have spatial autocorrelation, allowing the classification of municipalities according to their arrangement in the quadrants of the Moran Scatterplot, with two uniform classes: high with high neighborhood (1st quadrant), for municipalities that have spatial correlation and have high values; low with low neighborhood (2nd quadrant), for municipalities that present spatial correlation and have low values; as well as two other classes for outliers: high with low neighborhood (3rd quadrant), for municipalities that present spatial correlation, but have neighbors with low values; low with high neighborhood (4th quadrant), for municipalities that have spatial correlation, but have neighbors with high values.

The results were validated by applying a significance test using random permutation, in which 999 permutations were performed, with a 95% confidence level. Additionally, the Z score and p-value were determined, both measured based on the statistical significance that indicates whether the visible similarity (clusters of high or low values) or dissimilarity (outliers) is more pronounced than in a random distribution.

A positive and high Z score indicates that the data present clusters with high or low values, relating to the occurrence and size of the uniform classes (1st and 2nd quadrants). Meanwhile, a negative and low Z score indicates a statistically significant spatial data outlier. A p-value < 0.001 indicates that Global Moran's Index is considered significant.

The data from this study were organized in Microsoft Office Excel® 2019 spreadsheets and R version 4.0.2 to produce graphs and tables. The geoprocessing of Moran maps was performed in the free software TerraView, and the map formulation layouts were developed using QGIS 2.18.9. To develop the Kernel maps, the QGIS software was used, which has the heat maps feature, in which the Silverman quartic function was selected.[12] For the distribution and Kernel maps, the classes were stratified by quartile.

The study did not require submission to the Research Ethics Committee, in accordance with section III of Resolution 510/2016 of the Brazilian National Health Council, as the data obtained was secondary and publicly known.[16]

RESULTS

In spatial distribution analysis, of the 756,586 confirmed cases of HIV/AIDS, it is noteworthy that the Southeast region accounted for more than 348,400 (46.0%) of the cases between 2000-2019 (Figure 2A), mainly in the states of São Paulo (181,204 cases), Rio Grande do Sul (South), Bahia (Northeast), Pará (North) and Goiás (Midwest) (Figure 2B) and large extensions of low concentration clusters in the countryside regions of Bahia, Piauí and Tocantins, and in the West of Amazonas and Acre. In the coastal regions, in the South and Southeast, higher occurrences of the medium and high-risk classes are observed (Figure 2C).

When comparing the two decades 2000-2009 and 2010-2019, an increase was noted in areas of medium and high density of prevalence of cases in the Southeast and Northeast regions in the second decade. Among the top five states in the country, those that showed the most cases were São Paulo (23.0%), Rio de Janeiro (12.9%), Rio Grande do Sul (10.6%), Minas Gerais (7.3%) and Santa Catarina (5.4%). Meanwhile, the states of Acre (0.15%), Amapá (0.3%), Roraima (0.3%), Tocantins (0.3%) and Sergipe (0.6%) showed a lower frequency (Figure 3).

Concerning deaths, 232,892 deaths were recorded, with the highest mortality rates occurring in Rio Grande do Sul (12.30/100,000 inhab.) and Rio de Janeiro (10.50/100,000 inhab.), regardless of the period (Figure 4).

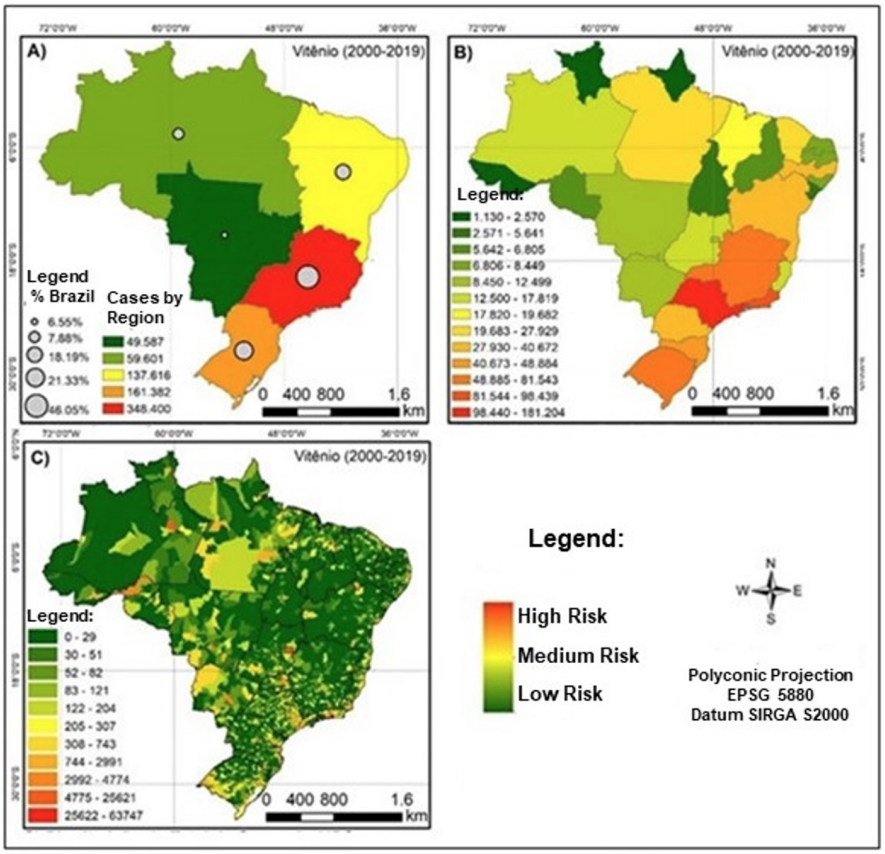


Figure 2. Map of the distribution of HIV/AIDS cases in regions (A), states (B) and municipalities (C) of Brazil between 2000 and 2019.

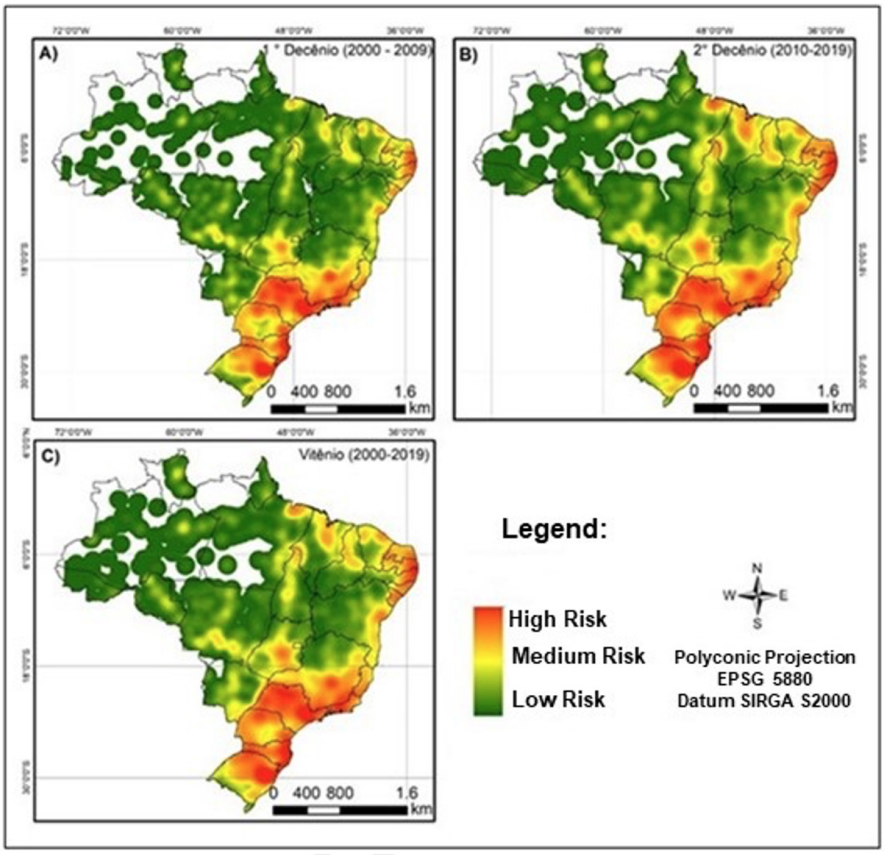


Figure 3. Kernel map of the prevalence rate of HIV/AIDS cases according to the first decade (2000-2009) (A), second decade (2010-2019) (B) and total period (2000-2019) (C) in Brazilian municipalities between 2000 and 2019.

It was observed that, in A and B, the high-value clusters extend over the Southeast, South and Midwest. Meanwhile, practically the entire Northeast is classified as a low-value cluster. The North region presented three low-value clusters in A, while in B there were low-value classes. Both present occasional occurrences of outliers, and it is important to highlight a small high-value cluster in Belém do Pará for both images. Global Moran's Index reflects the average positive spatial autocorrelation (p-value <0.001) (Figure 5).

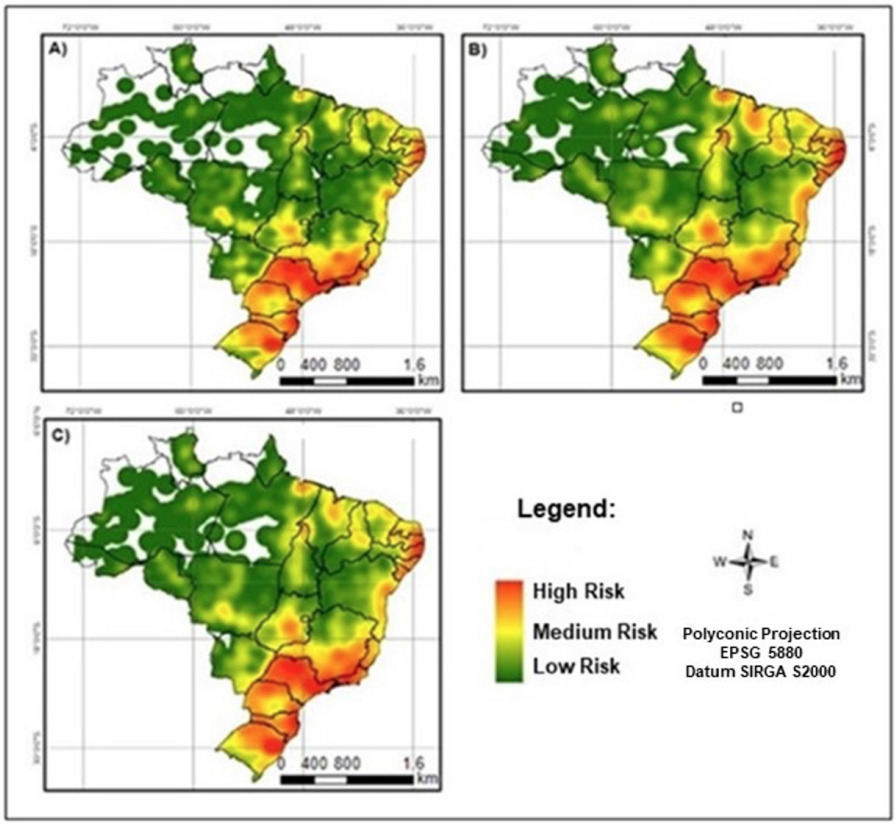


Figure 4. Kernel maps of the HIV/AIDS mortality rate according to the first decade (2000-2009) (A) second decade (2010-2019) (B) and total period (2000-2019) (C) in Brazilian municipalities between 2000 and 2019.

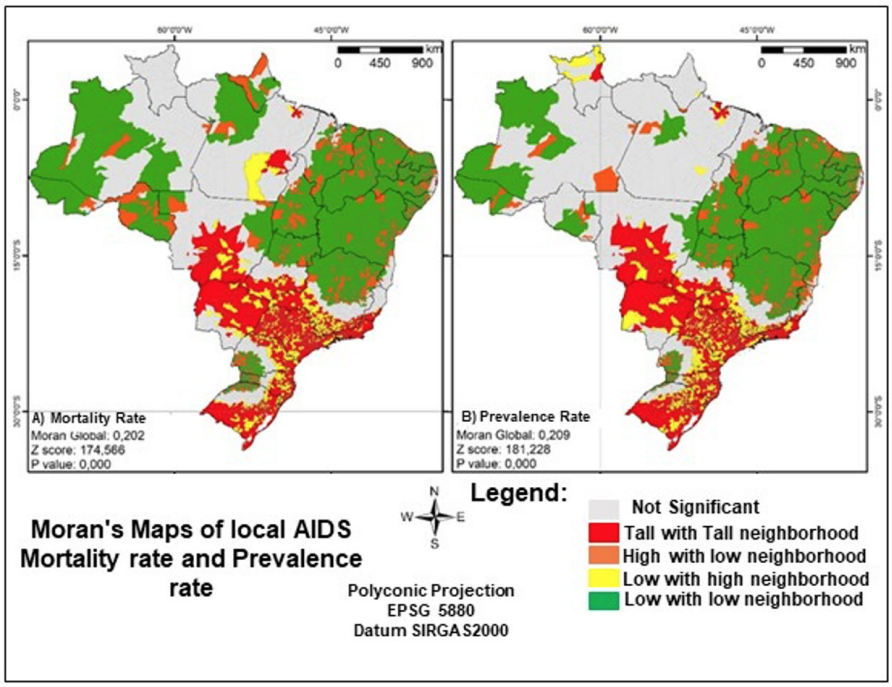


Figure 5. Moran Local Map of HIV/AIDS mortality rates (A) and HIV/AIDS prevalence rate (B) in Brazil between 2000 and 2019.

DISCUSSION

The distribution of HIV/AIDS in Brazil found in the study is not homogeneous across the Brazilian territory. The highest concentration of cases and deaths occurred in the Southeast and South geographic regions, which have populous states, large urban centers and municipalities with greater socioeconomic and demographic flow.[17] The geographical differences identified in this study showed a greater concentration of confirmed cases in the states of São Paulo and Rio de Janeiro, and deaths in Rio Grande do Sul, Rio de Janeiro and Santa Catarina prevailed.

In spatial analysis of Figure 2A, the Southeast region had the highest concentration of cases, being the region of greatest concern regarding HIV infection in the country. This is probably related to the high prevalence, taking into account population density. The states in the Southeast region are the most populous, with a large concentration of people.[17] Furthermore, the literature shows that the initial emergence of the spread of HIV/AIDS in Brazil occurred primarily in urban areas of the Rio de Janeiro-São Paulo axis, states located in this region, gradually expanding to other regions of the country. Initially, it reached the large metropolises and, later, reached the more remote areas with smaller cities. Therefore, it is plausible to suggest that the results of this study can be partially attributed to the historical trajectory of the spread of the epidemic in the country.[18]

A study carried out on HIV/AIDS cases in southeastern Brazil identified that their concentrations are related to the sociodemographic and socioeconomic flow of territories and that geographical differences influence the increasing risk in the distribution of the disease in space. [18] The cases are concentrated in socioeconomically vulnerable population groups, marked by social inequalities.[18] In Figure 2C, it was identified that the areas where large extensions of the low-density classes of the states occurred are marked by low population density and municipalities of large territorial extension. While in the coastal regions, in the South and Southeast, there are greater occurrences of medium and high-density classes, due to the high population density, but little apparent because of the small size of most municipalities in the region. In the Kernel maps of the prevalence rate, it is possible to better distinguish the influence of these municipalities.

In the map in Figure 3A, B and C, a relevant prevalence was observed in the Southeast region. This may be related to the economy, culture and social factors that influence a higher prevalence of the infection, given that people with low socioeconomic conditions, digitally excluded populations, migrants, injecting drug users, sexual partnerships with high-risk individuals, among other social vulnerabilities, are some characteristics for the tendency of this disease.[19] Furthermore, this scenario is worse in regions with less digital infrastructure, where educational campaigns do not effectively reach the most vulnerable communities.[19,20]

Meanwhile, the North region presented a low density of HIV/AIDS prevalence, which may be related to the fact that this region has a low population index and does not have metropolitan centers with characteristics conducive to dissemination.[20]

The finding regarding the increase in areas of medium and high concentration of the prevalence of HIV/AIDS cases, in spatial analysis, between 2010-2019, may be related to the fact that there is still no wider testing for the disease and the lack of adherence to immediate treatment in the event of a positive diagnosis, as these factors are essential for reducing cases and deaths.[19]

In mortality coefficient analysis, the South stood out more, and in a study on deaths from HIV/AIDS in Brazil, between 2000 and 2015, a worrying scenario was identified throughout the country[21]. In a study on the trend of mortality from HIV/AIDS and sociodemographic characteristics, in the states of Porto Alegre and Rio Grande do Sul, an increase in the number of deaths in women, of mixed race/color and older ages was identified. [22] This may be related to lack of adherence to ART, cultural and social factors, and mitigation strategies.[22] In contrast, mortality data from this infection showed a decrease in the total period in the current study.

The Plan of Action for the prevention and control of HIV and sexually transmitted infections 2016-2021 aims to eradicate the epidemic in the Americas by 2023, but it failed to achieve this goal. Despite advances, such as the expansion of ART and reduction in infections, the challenges of insufficient testing and unequal access have limited the achievement of this goal. However, in the Latin American region, of which Brazil is a part, mortality decreased from 41,000 to 37,000 between 2010 and 2019, evidencing a significant decrease.[23]

However, in a study on the competing risks model for analyzing mortality from HIV/AIDS in Brazil,[5] it was pointed out that, despite diagnosis and treatment being made available by the SUS and a reduction in the number of deaths, as found in this present study, the major problem in the country is the challenge of controlling the disease incidence. This may be related to treatment abandonment, multiple sexual partners without condoms, injectable drug use and late diagnosis.[24] Therefore, promoting testing and early diagnosis, implementing public policies for integration with the service and intensifying prevention and harm reduction are strategies to reduce incidence.

In the Kernel map analysis in Figure 4, it was identified that Rio Grande do Sul has the highest density of deaths. This state has late access to HIV/AIDS diagnosis, a long start of treatment for the virus infection and a medium percentage of individuals who abandon treatment, in addition to existing inequalities in access to treatment services for the disease.[9]

In a study conducted in three specialized HIV/AIDS services in Porto Alegre, in the state of Rio Grande do Sul, it was found that most men know their HIV status due to other diseases, such as tuberculosis, chest pain, donating blood or after numerous visits to healthcare services. However, spontaneous testing only occurs after the perception of some possible risk of infection, symptoms or guidance from someone,[24] which can lead to a delay in

diagnosing the disease and reflect in the increase in the number of deaths in the state.

Comparing the Kernel maps of mortality and prevalence rates, a smaller spread of the medium density class was observed. Furthermore, the regions classified as high density appear on the prevalence rate map with a more concentrated focus, while a smoother spatialization is observed on the mortality rate maps. This difference is due to the variation in the values of confirmed cases of HIV/AIDS, which is much higher than the variation in the occurrence of deaths due to HIV/AIDS.

In the analysis using Local Moran's Index on the map in Figure 5A and B, clusters were found in the Southeast, South and Midwest regions. The presence of HIV/AIDS in some regions may be related to the occurrence of specific factors, such as patterns of sexual relations, low condom use, socioeconomic conditions and neglect of healthcare in limited access to healthcare services, regular testing infrastructure.[17] Thus, as they are regions with large cities with high population density, they have greater risks for the disease,[5] while, in the Northeast and North regions, the clusters presented low values, and this may be related to the fact that the classification of many diseases is affected by underreporting, an issue frequently associated with the Northeast region.[25] However, according to literature, the largest increases have resulted in ignorance of the positive result and late access to treatment, resulting in death.[21]

In the different spatial analyses, the Kernel analysis showed the concentration of prevalence in the Southeast, South and Midwest, and Moran's Index had high-value clusters in these regions. Furthermore, there was a low risk of contamination and deaths in the Northeast and Midwest in both analyses. Furthermore, it is inferred that, in locations with more cases, there is a high risk of death from opportunistic diseases due to inadequate adherence to ART, late diagnosis and socioeconomic and structural factors.[22]

This current study has limitations, as it is based on secondary data that may be underreported, which may not demonstrate an accurate analysis of reality. To this end, analyses of duplications, inconsistencies and incompleteness in database were carried out, observing the variables analyzed.

Finally, it can be concluded that, in this study, it was noted that the Southeast region presented the highest cases and deaths, followed by the South, representing the regions with the highest densities, with the highest concentrations of cases in the states of São Paulo (Southeast region) and deaths in Rio Grande do Sul (South region). This is a public health concern that requires greater investment for the development of HIV science, making it relevant to carry out its monitoring, discussions and continuous actions in regions with the highest risks to achieve disease control with comprehensive, equitable and universal care.

Furthermore, it is important to conduct future studies that explore the determining factors of observed regional inequalities, including qualitative and quantitative analyses on the social determinants of health and the impact of local interventions. Furthermore, it is recommended to continuously monitor the epidemic and implement innovative approaches to predict trends and identify critical areas, aiming to achieve disease control.

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AUTHORS' CONTRIBUTIONS

Isadora Sabrina Ferreira dos Santos contributed to project administration, literature research, formal analysis, conceptualization, methodology, data curation, statistics, writing (first draft, review and editing), investigation, resources, software, supervision, validation, conclusions. **Laís Eduarda Silva de Arruda** contributed to writing (review and editing), interpretation of results, conclusions, validation and visualization. **José Thiago de Lima Silva** contributed to project administration, methodology, interpretation of results and review. **Guilherme Lira** contributed to data curation, software, interpretation of results, and review. **Emília Carolle Azevedo de Oliveira** contributed to project administration, literature search, formal analysis, writing (review and editing), investigation, methodology, resources, supervision, validation, and conclusions.

All authors have approved the final version of the manuscript and are responsible for all aspects of it, including ensuring its accuracy and integrity.