







# Temporal and spatial dynamics of mortality from cerebrovascular diseases in older adults in Brazil, 2008–2022

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## Abstract

**Objective:** To analyze the epidemiological profile and the temporal and spatial dynamics of mortality from cerebrovascular diseases in older adults in Brazil. **Method:** Ecological study with temporal trend and spatial analysis. Data were obtained from the Mortality Information System of the Department of Informatics of the Brazilian Unified Health System (SIM/DATASUS), covering the period from 2008 to 2022. Cerebrovascular disease was used as the underlying cause of death. For the temporal trend analysis, Brazilian regions were adopted as the units of analysis. For the spatial analysis, Brazilian municipalities were considered as the geographic units. **Results:** A total of 1,233,337 deaths from cerebrovascular diseases in older adults were recorded between 2008 and 2022, corresponding to a mortality rate of 328.386 per 100,000 inhabitants. There was a predominance among individuals aged 80 years or older (45.12%), those identified as White (52.45%), and individuals with low educational attainment, concentrated among those with no formal education (24.39%) or between one and three years of schooling (25.84%). A decreasing temporal trend in mortality was identified across all regions of the country, although the values remain high. Spatial analysis revealed a heterogeneous distribution of mortality, with a predominance of high-mortality clusters in the Northeast and South regions, as well as more localized clusters in the North region. **Conclusion:** There is a decreasing temporal trend in mortality from cerebrovascular diseases among older adults in Brazil, despite the persistence of high rates. The presence of spatial clusters of high mortality, particularly in the Northeast and South regions, reflects the structural, regional, and socioeconomic inequalities that characterize the country, reinforcing the need for public policies that are sensitive to territorial specificities and health inequities.

## Keywords:

Cerebrovascular Diseases. Stroke. Mortality. Spatial Analysis. Aged.

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## INTRODUCTION

Population aging is a global and irreversible phenomenon. According to the United Nations (UN), the world population is aging rapidly, and it is estimated that by 2050 the number of individuals aged 65 years or older will reach 1.6 billion, representing more than 16% of the global population<sup>1</sup>.

According to data from the Brazilian census, whereas in 2010 the proportion of individuals aged 60 years or older corresponded to 10.8% of the population, in 2022 this proportion increased to 15.8%<sup>2</sup>. In addition to changes in Brazil's demographic profile, there is also the epidemiological transition, characterized by shifts in morbidity and mortality patterns, with infectious diseases being gradually replaced by noncommunicable diseases (NCDs)<sup>3</sup>.

Considering the general population, without age stratification, approximately 75% of deaths are attributed to NCDs<sup>4</sup>. Within this group, cerebrovascular diseases stand out as the second leading cause of death worldwide. Among Latin American countries, Brazil has one of the highest mortality rates, despite a decline in recent years<sup>4</sup>.

Chronic diseases may lead to continuous medication use, increased dependence on family members, caregivers, and healthcare services, and higher costs for both families and the State<sup>5</sup>. The magnitude of the burden imposed by chronic diseases is evidenced by indicators such as disability-free life expectancy, which can be used to estimate the expected gains from reducing or eliminating these conditions<sup>6</sup>.

Although global rates of incidence, prevalence, and disability due to cerebrovascular diseases have shown a decreasing trend in recent years, analysis of absolute numbers indicates an increase in cases, disabilities, and deaths<sup>7</sup>.

Cerebrovascular diseases comprise a group of conditions related to cerebral circulation, classified in Chapter IX of the International Classification of Diseases, 10th Revision (ICD-10: I60–I69), encompassing different clinical entities, including cerebrovascular accident (CVA)<sup>8</sup>, the main acute event associated with high mortality and disability.

Given this context and the complexity imposed by Brazil's continental dimensions, ecological studies using different methodologies have been employed as valuable analytical tools, as they allow the investigation of populations of interest while also providing evidence to support the development of public policies with the potential to improve population health<sup>9,10</sup>.

Despite the relevance of cerebrovascular diseases in the context of public health and population aging, studies that jointly analyze temporal trends and spatial distribution of mortality over extended periods at municipal and regional levels remain scarce. In this context, the present study seeks to expand the understanding of mortality patterns from these diseases in Brazil, focusing on older adults, as this age group is the most affected and at higher risk of mortality and adverse outcomes.

The findings have relevant potential for the field of Geriatrics and Gerontology, providing evidence to support researchers, policymakers, and healthcare professionals in planning strategic actions aimed at population aging. Therefore, this study aimed to analyze the epidemiological profile and the temporal and spatial dynamics of mortality from cerebrovascular diseases in older adults in Brazil.

## METHODS

This ecological study with temporal trend and spatial analysis was conducted using secondary data obtained from the Mortality Information System of the Brazilian Unified Health System (SIM/SUS), available in the electronic database of the Department of Informatics of the SUS (DATASUS). Mortality from cerebrovascular diseases, defined as the underlying cause of death, was analyzed among older adults residing in Brazil, using Brazilian regions as the units of analysis for temporal trend assessment and municipalities as the units for spatial analysis over the last 15 years.

The identification of cerebrovascular diseases recorded as the underlying cause of death was performed using diagnostic categories according to Chapter IX of the International Classification of

Diseases, 10th Revision (ICD-10: Diseases of the circulatory system), categories I60 to I69.

Epidemiological variables (sex, age group, marital status, race/ethnicity, and educational attainment) were included exclusively to characterize the profile of deaths from cerebrovascular diseases in the older population and were used only for descriptive analysis, without temporal stratification or inferential analysis. All deaths among individuals aged 60 years or older residing in Brazil were considered according to the year of registration.

Descriptive analysis was performed using absolute frequencies and percentages for both sociodemographic variables and the main categories of cerebrovascular diseases. The mean mortality rate was calculated by dividing the number of deaths among older adults due to cerebrovascular diseases by the population of older adults residing in the same year and location, multiplied by 100,000 population.

To describe mortality trends in Brazil, data from the five Brazilian regions were analyzed for the period from 2008 to 2022, considering population data for each respective year. Population data were based on the 2010 and 2022 demographic censuses and intercensal estimates provided by the Brazilian Institute of Geography and Statistics (IBGE) for each year analyzed.

Temporal trend analysis was performed using the Joinpoint Regression Model. This model enabled the calculation of the Annual Percent Change (APC) and the Average Annual Percent Change (AAPC). Trends were classified as stationary, increasing, or decreasing according to the slope of the regression line. Trends were expressed as APC and AAPC and were considered stationary when the regression coefficient did not differ significantly from zero ( $p > 0.05$ ).

For spatial analysis, the units of analysis comprised the 5,568 Brazilian municipalities and the Federal District, as recorded in the 2022 demographic census, along with mortality data for older adults across the study period obtained from DATASUS information systems. Population data for all municipalities between 2008 and 2022 were considered.

The mortality rate from cerebrovascular diseases in older adults was calculated for the study period. The numerator corresponded to the mean number of deaths due to cerebrovascular diseases among individuals aged 60 years or older during the period, and the denominator corresponded to the resident older population in Brazilian municipalities in 2015, multiplied by 100,000 inhabitants. The choice of 2015 was based on it being the midpoint of the study period and therefore representative of the average population. Spatial distribution was assessed using exploratory data analysis, generating a choropleth map of mortality rates from cerebrovascular diseases among older adults in Brazilian municipalities. The map was presented in quartiles, with darker shades indicating higher mortality rates.

Spatial autocorrelation was assessed using the Global Moran's I for mortality rates among older adults. Positive values (between 0 and +1) indicated direct spatial autocorrelation, while negative values (between 0 and -1) indicated inverse spatial autocorrelation. The Local Indicators of Spatial Association (LISA) were used to generate maps identifying areas with statistically significant local spatial autocorrelation, allowing the detection of clusters and spatial outliers.

The Moran scatterplot was used to evaluate spatial autocorrelation of mortality rates from cerebrovascular diseases, comparing the observed value in each municipality with the mean value of neighboring municipalities. The plot is divided into four quadrants representing different spatial association patterns. The High-High quadrant (Q1) indicates municipalities with high rates surrounded by municipalities with similarly high rates, while the Low-Low quadrant (Q2) represents areas with low rates among neighbors with similar values, indicating positive spatial association. The High-Low (Q3) and Low-High (Q4) quadrants indicate negative spatial association, identifying municipalities with values that differ from their surroundings, characterized as spatial outliers. Associations with  $p < 0.05$  were considered statistically significant.

Brazil's digital cartographic base was obtained in shapefile format using the SIRGAS 2000 Geodetic Reference System (Geocentric Reference System for the Americas), updated in 2022.

Approval from a Research Ethics Committee was not required, as secondary data from the Brazilian Ministry of Health website were used. These data are publicly available and do not allow individual identification, in accordance with National Health Council Resolution No. 510/2016.

## DATA AVAILABILITY

The complete dataset supporting the findings of this study is publicly available on Figshare

and can be accessed at <https://doi.org/10.6084/m9.figshare.31175437>.

## RESULTS

During the study period, a total of 1,233,337 deaths from cerebrovascular diseases were recorded among individuals aged 60 years or older in Brazil, corresponding to a mortality rate of 328.386 per 100,000 inhabitants. Table 1 presents the epidemiological profile of individuals who died during the period from 2008 to 2022.

**Table 1.** Epidemiological characteristics of mortality from cerebrovascular diseases among older adults in Brazil, 2008–2022.

Variables	(N – %)
Sex	
Female	(621,291 – 50.37)
Male	(611,942 – 49.62)
Unknown	(104 – 0.01)
Age group	
60-69	(272,233 – 22.07)
70-79	(404,626 – 32.81)
80 or older	(556,478 – 45.12)
Marital status	
Married	(439,691 – 35.65)
Widowed	(429,015 – 34.78)
Single	(189,753 – 15.39)
Separated	(62,739 – 5.09)
Other	(20,110 – 1.63)
Unknown	(92,029 – 7.46)
Race/ethnicity	
White	(646,897 – 52.45)
Mixed-race	(416,037 – 33.75)
Black	(104,999 – 8.51)
Asian	(8,154 – 0.66)
Indigenous	(2,288 – 0.18)
Unknown	(54,962 – 4.45)
Education (years of schooling)	
None	(300,893 – 24)
1 to 3	(318,713 – 25.84)
4 to 7	(211,721 – 17.17)
8 to 11	(100,011 – 8.11)
12 or more	(38,804 – 3.15)
Unknown	(263,195 – 21.34)
<b>TOTAL (n – %)</b>	<b>(1,233,337 – 100.00)</b>

**Source:** Ministry of Health. Mortality Information System of the Brazilian Unified Health System (SIM/SUS).

Among deaths from cerebrovascular diseases, classified according to ICD-10 codes, deaths were recorded for conditions related to eight categories, and no deaths were reported for categories I65 (Occlusion and stenosis of precerebral arteries, not resulting in cerebral infarction) and I68 (Cerebrovascular disorders in diseases classified elsewhere) (Table 2).

Table 3 presents the temporal trend of deaths from cerebrovascular diseases across the regions of Brazil. Decreasing trends were observed in all five regions, as well as for Brazil overall. The Northeast and Central-West regions showed declining trends throughout the entire study period. The Southeast and South regions demonstrated a reduction only during the period from 2008 to 2020, although with greater magnitudes of decline, a pattern similar to that observed for Brazil as a whole. In contrast, the North region exhibited a distinct pattern, with decreasing trends between 2008–2010 and 2015–2022, but a slight increasing trend between 2010 and 2015. When evaluating the average trend (AAPC), a decreasing trend was observed in all Brazilian regions, with the Southeast and South regions showing the greatest reductions.

Figure 1 presents the spatial analysis of mortality from cerebrovascular diseases in Brazilian municipalities for the period from 2008 to 2022. Figure 1A shows, through a choropleth map, that darker shading corresponds to higher mortality rates from cerebrovascular diseases. High rates were observed in municipalities across all Brazilian states, particularly in municipalities along the northeastern coast and throughout the states of Maranhão and Piauí, as well as in municipalities in the South region, especially in the states of Rio Grande do Sul and Paraná.

In the spatial autocorrelation analysis (Figure 1B), areas exhibiting spatial dependence were identified, as evidenced by the presence of clusters classified in quadrant Q1 (High-High), which represent clusters of municipalities with high mortality rates from cerebrovascular diseases surrounded by neighboring municipalities that also present high rates. These clusters were identified in municipalities in Northeastern states such as Paraíba, Pernambuco, Alagoas, and Sergipe, in virtually all municipalities in the state of Piauí, and in the northern and southern areas of Maranhão. In the North region, clusters were identified in the states of Amazonas and Pará, and in the South region, in the states of Santa Catarina and Rio Grande do Sul.

**Table 2.** Deaths from cerebrovascular diseases by ICD-10 category among older adults, Brazil, 2008–2022.

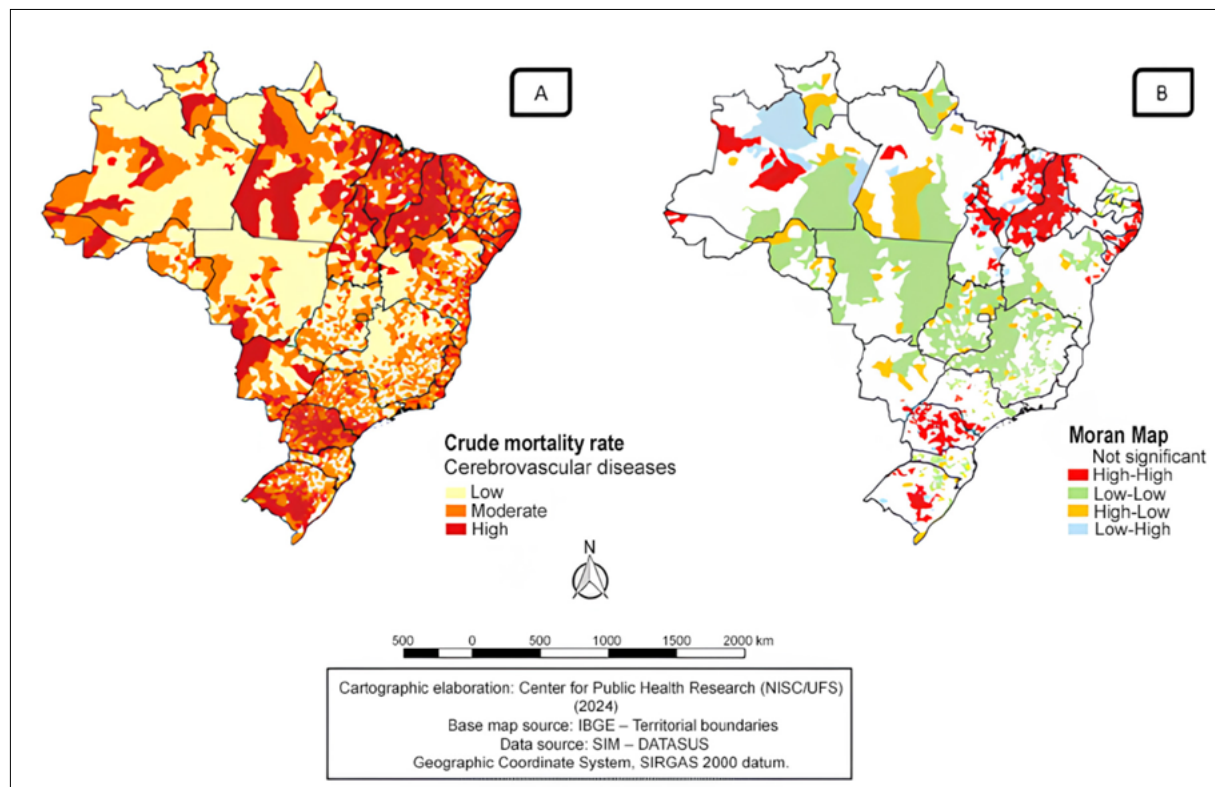
Code – ICD-10	Category – ICD-10	Total deaths	%
I60	Subarachnoid hemorrhage	35,031	2.84
I61	Intracerebral hemorrhage	147,364	11.95
I62	Other nontraumatic intracranial hemorrhage	14,907	1.21
I63	Cerebral infarction	87,403	7.09
<b>I64</b>	<b>CVA, not specified as hemorrhagic or ischemic</b>	<b>519,251</b>	<b>42.10</b>
I66	Occlusion and stenosis of cerebral arteries, not resulting in cerebral infarction	1	0.00
I67	Other cerebrovascular diseases	188,752	15.30
I69	Sequelae of cerebrovascular diseases	240,628	19.51
<b>Total</b>		<b>1,233,337</b>	<b>100</b>

**Source:** Ministry of Health. Mortality Information System of the Brazilian Unified Health System (SIM/SUS).

**Table 3.** Temporal trend of deaths from cerebrovascular diseases among older adults by region of Brazil, 2008–2022.

Region	(APC)*	Trend	(AAPC)**	Trend
North	2008-2010:-4.4259***	Decreasing	-1.7175***	Decreasing
	2010-2015:0.7691***	Increasing		
	2015-2022:-2.6821***	Decreasing		
Northeast	2008-2022:-2.3078***	Decreasing	-2.3078***	Decreasing
Southeast	2008-2020:-3.8051***	Decreasing	-3.1173***	Decreasing
	2020-2022:1.1143	Stationary		
South	2008-2020:-4.2920***	Decreasing	-3.2259***	Decreasing
	2020-2022:3.4247	Stationary		
Central-West	2008-2022:-2.7305***	Decreasing	-2.7305***	Decreasing
Brazil	2008-2016:-2.9248*	Decreasing	-2.7241*	Decreasing
	2016-2020:-4.0345*	Decreasing		
	2020-2022:0.7800	Stationary		

\*APC: Annual Percent Change; \*\*AAPC: Average Annual Percent Change; \*\*\*Statistically significant value:  $p < 0.05$ .



**Figure 1.** A: Spatial distribution of crude mortality rates from cerebrovascular diseases among older adults, by municipality, Brazil, 2008–2022. B: Spatial autocorrelation of mortality from cerebrovascular diseases among older adults, by municipality, Brazil, 2008–2022.

## DISCUSSION

During the study period, Brazilian municipalities exhibited spatial and temporal variations in mortality from cerebrovascular diseases among individuals aged 60 years or older. This finding highlights the epidemiological complexity of a country with continental dimensions and substantial socioeconomic and demographic diversity.

Despite the declining trend in mortality rates nationwide, high absolute numbers of deaths were still observed. Spatial analysis revealed clusters of high mortality in the Northeast and South regions, indicating areas of greater vulnerability. Spatial factors, as well as socioeconomic conditions and access to healthcare services, may influence the distribution of mortality from cerebrovascular diseases and may reflect regional inequalities and the need for targeted strategies.

Among cerebrovascular diseases, CVA constitutes the main clinical manifestation within this group of conditions and accounts for a high burden of mortality. In Brazil, CVA has been among the leading causes of death for more than three decades and, despite a reduction in mortality rates over this period, it still results in more than 100,000 deaths annually across all age groups<sup>11</sup>. This declining trend follows the global pattern and has been mainly attributed to advances in primary prevention, early diagnosis, and acute treatment. High rates are also observed in low- and middle-income countries, where stroke care is often inconsistent, fragmented, and associated with poor clinical outcomes<sup>7,11</sup>.

The high proportion of deaths classified under category I64 (cerebrovascular accident, not specified as hemorrhagic or ischemic), as well as the substantial contribution of category I69 (Sequelae of cerebrovascular diseases), warrants attention. The frequent use of code I64 may reflect limitations in the diagnostic process, particularly in settings where timely access to imaging or specialized services capable of distinguishing CVA subtypes is lacking. Similarly, the prominence of sequelae of cerebrovascular diseases (I69) may indicate both the cumulative burden of these conditions over time and weaknesses in continuity of care and longitudinal

follow-up of affected individuals. In this context, further studies are recommended to investigate the relationship between these findings and regional inequalities in the organization of emergency care networks, diagnostic capacity, and the quality of underlying cause-of-death reporting.

The reduction in mortality rates from cerebrovascular diseases in Brazil over time may be associated with advances in the national healthcare system. These include the implementation of Primary Health Care (PHC) in 1994, the development of CVA care units starting in 2012, and the establishment of the Strategic Action Plan to Tackle Noncommunicable Diseases in Brazil in 2011<sup>4</sup>.

According to Souza et al., strategic objectives defined in this Strategic Action Plan include reducing premature mortality, decreasing the prevalence of smoking and harmful alcohol consumption, increasing physical activity, promoting fruit consumption, and stabilizing the growth of obesity. All these initiatives represent important tools for prevention and early intervention and are therefore highly relevant for reducing deaths from cerebrovascular diseases in the country<sup>8</sup>. In this context, timely and effective care at every point along the care pathway is essential, which depends not only on the structure of the healthcare network but also on the preparedness of healthcare professionals and the population's level of health literacy, factors that must be coordinated to ensure appropriate patient referral<sup>12</sup>.

Local studies have shown that insufficient investment in public health may hinder reductions in mortality indicators, reinforcing that local conditions and healthcare financing are key determinants of more favorable outcomes<sup>7</sup>. Health education plays a central role in prevention strategies, particularly in the early recognition of the signs and symptoms of cerebrovascular diseases such as CVA, facilitating timely care-seeking and thereby reducing mortality risk. The implementation of care pathways should be accompanied by continuing education programs to ensure that healthcare teams are adequately trained to provide effective and high-quality care<sup>9,13</sup>.

A previous study<sup>4</sup> that analyzed trends in cerebrovascular mortality in Brazil and its association with Human Development and Social Vulnerability

found that the Southeast and South regions had higher absolute rates but showed significant declines, whereas the North and Northeast regions, despite initially presenting lower rates, exhibited increases during certain periods. According to the authors, this heterogeneous pattern reflects social, economic, demographic, and epidemiological differences between regions, including educational attainment, income, access to healthcare services, and coverage of specialized units<sup>4</sup>.

This scenario reflects the profound socioeconomic inequality in the country, which is expressed in marked differences in life expectancy across Brazilian regions and directly influences mortality patterns. These inequalities are also reflected in regional differences in life expectancy, which are higher in southern states and lower in the Northeast region<sup>2</sup>. The greater clustering of deaths observed in southern states may be associated with higher life expectancy in these areas. Considering that the risk of death from cerebrovascular diseases increases substantially with advancing age, particularly from 80 years onward, the larger proportion of individuals in older age groups contributes to the increased mortality observed.

The concentration of mortality in more advanced age groups reinforces the role of population aging and the accumulation of risk factors over the life course in the dynamics of cerebrovascular diseases. It is important to consider that the observed reduction in mortality rates may be partially associated with the so-called 'denominator effect': as the older population increases, the absolute number of deaths tends to be diluted within a larger population base, potentially reducing rates without necessarily reflecting a decrease in individual risk of death. Additionally, older age groups often include individuals who accumulate multiple risk factors for cerebrovascular diseases, such as hypertension, dyslipidemia, diabetes, and smoking<sup>4,14</sup>.

This study identified a predominance of deaths from cerebrovascular diseases among White older adults. However, age- and race/ethnicity-adjusted analyses have shown that the risk of cerebrovascular mortality is higher among Black individuals, followed by Mixed-race individuals, and lower among White individuals<sup>15</sup>. This apparent paradox may

be explained by differences in life expectancy across racial groups: while White women live, on average, up to 80 years, Black women live approximately 76 years; among men, life expectancy is 74.5 years for White individuals and 68.6 years for Black individuals<sup>16</sup>. Thus, the higher absolute number of deaths among White individuals may reflect not a higher risk, but a greater likelihood of surviving to older ages, when cerebrovascular diseases are more frequent and lethal. Conversely, lower survival among Black and Mixed-race populations may reduce their likelihood of reaching these more vulnerable age groups, reflecting historical and structural health inequalities.

The data also showed that most deaths occurred among individuals with lower levels of educational attainment. Unfavorable socioeconomic conditions may limit access to health information, hinder the acquisition of healthy foods, reduce the availability of adequate spaces for physical activity, and restrict access to healthcare technologies<sup>14</sup>. These factors are compounded by the impact of low educational attainment, which limits access to education and reduces awareness of health issues, thereby influencing the adoption of healthy behaviors and the capacity for social mobilization aimed at improving quality of life<sup>17-19</sup>.

The North and Northeast regions showed the smallest reductions in mortality rates from cerebrovascular diseases during the study period. Consistent with the literature, a previous study<sup>20</sup> found that these regions exhibited less pronounced declines and, in some municipalities, increases in mortality rates, possibly influenced by socioeconomic factors, access to healthcare services, underreporting, and delayed demographic transition.

In different countries, individuals with lower income tend to use healthcare services less frequently, mainly due to access barriers, resulting in poorer health conditions. This situation is also evident within countries. In Brazil, small differences in monthly household per capita income are sufficient to identify older adults with poorer health conditions, lower physical mobility, and reduced use of healthcare services. Therefore, it is essential to consider the socioeconomic context of different

locations in order to develop and implement policies tailored to each social context.

Further supporting the impact of socioeconomic factors on mortality rates from cerebrovascular diseases, the Global Burden of Disease study (2015) showed that the greatest reductions in mortality rates occurred in Brazilian states within the highest development tertile<sup>4</sup>. This finding helps explain the prominence of the Northeast region in terms of high mortality rates observed in municipal-level crude mortality maps and spatial autocorrelation analyses. In this context, the combination of high numbers of deaths and a slow demographic transition contributes to higher mortality rates compared with other regions of the country.

Although the data used were obtained from official records, the possibility of underreporting and inconsistencies in the completion of death certificates, as well as regional variations in the quality of information recorded in the Mortality Information System, cannot be ruled out. The high use of nonspecific diagnostic categories, such as I64 and I69, may also reflect limitations in access to diagnosis and heterogeneity in the structure of healthcare services; therefore, the results should be interpreted with caution. The use of a fixed denominator (2015 population) for the mortality rate in the spatial analysis represents an approximation for the period and may distort absolute levels in municipalities with substantial population variation. Furthermore, given the ecological study design, the findings do not allow for individual-level inferences or the establishment of causal relationships. Nevertheless, the analysis of deaths across the entire Brazilian territory represents an important methodological strength, as it allows for the representation of the reality of a country with continental dimensions over a 15-year period. Taken together, these limitations do not invalidate the findings, but reinforce the need to interpret them in light of regional inequalities and the structural conditions of the Brazilian healthcare system.

## CONCLUSION

The findings of this study indicate a decreasing temporal trend in mortality from cerebrovascular diseases among older adults in Brazil over the past 15 years, although rates remain high. Spatial analysis revealed the presence of regional clusters of high mortality, particularly in states in the Northeast and South regions, demonstrating a heterogeneous distribution across the national territory.

These findings reinforce the importance of public policies focused on prevention, early diagnosis, and comprehensive care for cerebrovascular diseases, taking into account regional and socioeconomic inequalities in the context of population aging in Brazil. Considering the inherent limitations of the ecological design, further studies using individual-level analytical approaches are needed to deepen the understanding of the determinants of cerebrovascular disease mortality among older adults and their impact on population aging.

## AUTHORSHIP

- Gabrielle Castro de Oliveira: conceptualization; data curation; methodology; writing, original draft; writing, review and editing.
- Marcus Valerius da Silva Peixoto: data analysis and interpretation; critical review; writing, review and editing; methodology.
- Júlia Guimarães Reis da Costa: writing, original draft; writing, review and editing; approval of the version to be published.
- Andrezza Marques Duque: responsible for all aspects of the study; project administration; conceptualization; data curation; writing, review and editing; methodology; funding acquisition.

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