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Incidence of Strokes in Brazil between 2018 and 2022 and their correlations with the COVID-19 pandemic

Incidência de Acidentes Vasculares Cerebrais (AVCs) no Brasil entre os anos de 2018 a 2022 e suas correlações com a pandemia do COVID-19

Incidencia de Accidente Cerebrovascular (ACV) en Brasil entre los años 2018 a 2022 y sus correlaciones con la pandemia de COVID-19

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Abstract
The present study provides a comprehensive analysis of the trends in Stroke (CVA) and COVID-19 in Brazil from 2018 to 2022. Using data provided by the Brazilian Ministry of Health, the incidence and mortality of these two diseases were examined in each of the five regions of Brazil and then compared with the country's population distribution. In this context, fluctuations in both the incidence and mortality of COVID-19 were observed in the Brazilian regions from 2020 to 2022. Overall, the proportions between the incidence of strokes and the population size remained stable in all regions, while the distribution of COVID-19 showed certain variations. There was an increase of more than 10% in the number of stroke hospitalizations in all five regions in 2022 compared to the initial year of the study in 2018. This trend was consistent across all regions, potentially suggesting a correlation between the increase in stroke hospitalizations and the COVID-19 pandemic. Based on this, it is suggested that further research be conducted to observe if these trends will continue over the years. The objective of the present study was to measure the variation in the incidence and deaths from stroke in Brazil from 2018 to 2022, and correlate them with the peak of the COVID-19 pandemic, analyzing if there was a correlation in the increase of cases of both diseases.
Keywords: Stroke; CVA; COVID-19; Sars-Cov-2; Brazil.

Resumo
O presente estudo apresenta uma análise abrangente acerca das tendências de Acidente Vascular Cerebral (AVC) e da doença causada pelo vírus Sars-Cov-2, COVID-19, no Brasil de 2018 a 2022. Utilizando dados disponibilizados pelo Ministério da Saúde do Brasil, foram examinados a incidência e a mortalidade dessas duas doenças em cada uma das cinco regiões do Brasil e, em seguida comparadas com a distribuição populacional do país. Nesse âmbito, observa-se flutuações tanto na incidência quanto na mortalidade no que tange a COVID-19 nas regiões brasileiras de 2020 a 2022. No geral, as proporções entre a incidência de AVCs e o tamanho populacional permaneceram estáveis em todas as regiões, ao passo que a distribuição de COVID-19 mostrou certas variações. Foi observado um aumento superior aos 10% no número de internações por AVCs em todos as cinco regiões no ano de 2022, em comparação ao ano inicial do estudo em 2018. Tal tendência foi consistente em todas as regiões, podendo dessa forma sugerir uma correlação entre o aumento no número de internações por AVCs associado à pandemia de COVID-19. Com base nisso, sugere-se a elaboração de mais trabalhos para se observar se tais tendências irão se manter com o passar dos

anos. O objetivo do presente trabalho foi o de mensurar a variação da incidência e dos óbitos por AVC no Brasil de 2018 a 2022, e correlacioná-los com o pico da pandemia de COVID-19, analisando se houve correlação no aumento de caso das doenças.
Palavras-chave: Acidente vascular cerebral; AVCs; COVID-19; Sars-Cov-2; Brasil.

Resumen
El presente estudio ofrece un análisis exhaustivo de las tendencias de Accidente Cerebrovascular (ACV) y la enfermedad causada por el virus Sars-Cov-2, COVID-19, en Brasil desde 2018 hasta 2022. Utilizando datos proporcionados por el Ministerio de Salud de Brasil, se examinaron la incidencia y la mortalidad de estas dos enfermedades en cada una de las cinco regiones del país, para luego compararlas con la distribución poblacional. En este contexto, se observan fluctuaciones tanto en la incidencia como en la mortalidad relacionadas con la COVID-19 en las regiones brasileñas de 2020 a 2022. En general, las proporciones entre la incidencia de ACV y el tamaño poblacional se mantuvieron estables en todas las regiones, mientras que la distribución de COVID-19 mostró ciertas variaciones. Se observó un aumento superior al 10% en el número de hospitalizaciones por ACV en todas las regiones en el año 2022, en comparación con el año inicial del estudio en 2018. Esta tendencia fue consistente en todas las regiones, sugiriendo así una correlación entre el aumento en las hospitalizaciones por ACV y la pandemia de COVID-19. En base a esto, se sugiere la elaboración de más trabajos para observar si estas tendencias se mantendrán en los próximos años. El objetivo del presente trabajo fue medir la variación en la incidencia y las muertes por accidente cerebrovascular en Brasil de 2018 a 2022, y correlacionarlas con el pico de la pandemia de COVID-19, analizando si hubo correlación en el aumento de casos de ambas enfermedades.
Palabras clave: Accidente cerebrovascular; ACV; COVID-19; Sars-Cov-2; Brasil.

1. Introduction

1.1 Cerebrovascular Accident

Cerebrovascular Accident (CVA) is a disease that affects the cerebral arteries, responsible for carrying and distributing blood to the brain. This disease is the 5th leading cause of death and one of the main causes of functional disability throughout the United States of America (American Stroke Association, 2022). In Brazil, according to the "Epidemiological Analysis and Surveillance of Non-Communicable Diseases" department of the Ministry of Health's health surveillance secretariat, cerebrovascular diseases ranked 2nd in the overall mortality survey of 2016 – the last one available – as well as holding the same position in the year 2000, in both cases behind ischemic heart diseases (Brazil, 2022). Regarding global mortality levels, Stuart Spencer's article "Global Burden of Disease 2010 study: A personal reflection" analyzed that ischemic heart diseases are the leading cause of worldwide death, representing 13.3% of the total, and following closely are CVAs, accounting for 11.1% of all fatalities (Spencer, 2013).

In China, since 2015, CVA has become the leading cause of death in the country, with an estimated total of 17.8 million cases of CVAs and 2.3 million deaths due to the disease in the year 2020 (Tu et al., 2023).

CVA occurs when a blood vessel that carries nutrients and transports oxygen to the brain bursts or is blocked by a clot. In such a situation, part of the brain cannot get the oxygen it needs, leading to the death of brain cells in the area that is no longer irrigated (American Stroke Association, 2022).

CVAs can be divided into ischemic, hemorrhagic, transient ischemic attack, and cryptogenic strokes. The ischemic type is the most common and occurs in situations where a vessel supplying blood to the brain is somehow obstructed. Hemorrhagic strokes usually occurs when a weakened vessel ruptures, which can be caused by the prior formation of an aneurysm at the site of future rupture or by the patient's arteriovenous malformations (AVMs). Uncontrolled high blood pressure is the main cause of hemorrhagic cerebrovascular accidents, as it leads to high pressure on the vessel’s walls. Transient ischemic attack, also called a mini-stroke, is caused by a temporary clot that momentarily blocks blood flow. This type of CVA should be taken as a warning sign and treated seriously, as it serves as an indicator for a potential future stroke of a more severe nature than the transient type. This means that, most of the time, there is an explicit cause, a clot that blocked the flow; however, in some cases, the cause remains undefined, and in these situations, it is termed a cryptogenic cerebrovascular

accident (American Stroke Association, 2022; Kaur et al., 2022).

In the United States, about 87% of all CVAs are of ischemic origin, while hemorrhagic strokes represent 13% of cases (Saine et al., 2021; American Stroke Association, 2022). Among ischemic cerebrovascular accidents, cardioembolism, large vessel atherosclerosis, and small vessel diseases are responsible for 65% of cases. Potentially modifiable risk factors are associated with 90% of the triggering risk of CVA, including hypertension, smoking, obesity, diet, sedentary lifestyle, diabetes, alcohol intake, psychosocial factors, and heart diseases (Caprio & Farzaneh, 2019; Ananth et al., 2022).

"The Global Burden of Disease (GBD)" is a project aimed at describing the epidemiology of major diseases, injuries, and their respective risk factors. According to the GBD 2010 publication, CVAs are the 2nd leading cause of death among all diseases worldwide, second only to ischemic heart diseases (Spencer S., 2013), and the 3rd most disabling disease – those ahead are ischemic coronary diseases and lower respiratory infections, respectively – (Murray et al., 2012, Rimelle & Thomalla, 2022).

Joosup Kim and colleagues' publication (2019) shows that incidence, lethality, and mortality statistics provide evidence that there is variation in the number of cases between high-income countries compared to those of medium or low income. Recent studies have demonstrated a higher age-adjusted overall incidence of CVAs in low- and middle-income countries than in high-income countries, a finding supported by Thomas B. H. Potter and colleagues (2022) (Kim et al., 2019, Potter et al., 2022).

An epidemiological study that evaluated the period from 1990 to 2010 estimated an annual incidence of 258 cases per 100,000 inhabitants worldwide and found considerable differences between high-income countries compared to low-income ones. The number of people suffering strokes under the age of 65 is considerably high and is growing proportionally more in low- and middle-income countries compared to high-income ones; more than 83,000 children and young people aged 20 or younger are affected by strokes annually worldwide (Feigin et al., 2014).

1.2 COVID-19

In recent decades, coronaviruses have been responsible for two large-scale pandemics, namely Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS) (Zhou et al., 2020; Hassan et al., 2021).

In late 2019, there was an outbreak of pneumonia in Wuhan, Hubei province, China, originating in a seafood market and rapidly spreading, affecting over 2,700 people and causing 80 deaths. By January 26th, 2020, it had spread to more than 10 countries. Clinical symptoms in these patients included fever, dry cough, dyspnea, headache, and pneumonia, which, in some cases, resulted in progressive respiratory failure due to alveolar damage and, in others, led to death (Zhou et al., 2020; Liu et al., 2020).

The responsible doctors determined that the disease was caused by a virus-induced pneumonia based on clinical symptoms and criteria such as an increase in body temperature, a decrease in the number of lymphocytes and white blood cells, and the presence of new lung infiltrates on chest X-rays without apparent improvement after three days of antibiotic treatment. Initially, all cases were centered around the seafood market in Wuhan but evolved into human-to-human transmission (Zhou, Peng, et al., 2020).

Based on this, samples from seven patients were sent to the laboratory of the Wuhan Institute of Virology to identify the pathogen causing the disease. After sequencing these samples, it was found that almost 90% of them corresponded to a sequence of SARS-CoV and shared approximately 80% of the sequence identity of the SARS-CoV Bj01 subtype. Following the naming previously established by the World Health Organization (WHO), it was called the novel coronavirus 2019 (COVID-19) (Zhou et al., 2020; Habas et al., 2020).

Shortly after, on February 26th, 2020, the first case in Brazil was confirmed for what was considered a public health

emergency of international concern under the 2005 International Health Regulations (PAHO/WHO, 2022). Since then, Brazil has recorded more than 34 million cases of COVID-19 and over 650,000 deaths (Brazil, 2023).

RNA viruses have a high mutation rate, higher than DNA viruses, which is why several variants of SARS-CoV-2 (COVID-19) have emerged. From January to September 2021, many of these mutations became epidemic strains in various countries, with four of them—Alpha, Beta, Gamma, and Delta—considered variants of concern by the WHO. Compared to the initial strain, these four showed mutations in the spike protein, resulting in increased transmissibility and production of immune escape. The B.1.1.529 variant (Omicron) was first identified in Africa at the end of 2021 and had the highest number of mutations at that time, leading to a transmissibility index 1.4 to 3.1 times higher than that of the Delta variant (Tian et al., 2022).

1.3 Neurological Damage Post COVID-19

The meta-analysis by Domenico Nuzzo and colleagues (2021) assessed that neurological damage post-COVID-19 varied from patient to patient, ranging from nonspecific symptoms, delirium, brain inflammation, nerve damage, to strokes; some of these symptoms, the more severe ones like strokes, became visible in a later stage of the disease (Nuzzo et al., 2021).

The study also showed that over 35% of severely hospitalized patients due to SARS-CoV-2 had a high probability of experiencing neurological symptoms, such as headache, altered level of consciousness, and paresthesia. Furthermore, it was observed that most patients recovered from SARS-CoV-2 persisted with at least one of the symptoms they had post-disease, whether respiratory or neurological in origin (Nuzzo et al., 2021).

Regarding the neurological symptoms in the Nuzzo et al. (2021) study, after 100 days of hospitalization, approximately 34% presented memory loss, 30.8% had sleep disturbances, 28% experienced difficulty concentrating, 16.8% dizziness, 13.1% vertigo, 5.6% altered taste, and 5.1% changes in smell. Neurological symptoms reported more than three weeks after the disease period were encephalopathy in 13%, neuropsychiatric diagnoses (psychosis, neurocognitive syndrome, and affective disorder) in 18%, and cerebrovascular events in 62%. Among hospitalized patients, neurological complications were observed in 84%, including encephalopathy (69%) and corticospinal tract symptoms (67%) (Nuzzo et al., 2021).

Available literature data show a total of 455 COVID-19 patients affected by ischemic stroke in a 2-month period between September and October 2020. The survey used data from publications worldwide available on PubMed and Google Scholar, most of which were case series or retrospective observational case reports. Of the total 455 patients affected by ischemic strokes, 59 reported their gender, with 16 women and 43 men, aged between 18 and 93 years. The majority had an anterior circulation origin and was due to embolic causes. According to the authors, the frequency of strokes did not correlate with the severity of COVID-19 (Finsterer et al., 2022).

This study aims to measure the variation in the incidence and number of deaths of patients who suffered strokes in Brazil from 2018 to 2022 and correlate the changes found with the period of the peak of COVID-19 cases in Brazil, analyzing whether there is a correlation in the increase of cases of both diseases.

2. Methodology

According to Carlos Estrela (2018), in an observational study the investigator may only observe the occurrence of a certain disease, without having control over the allocation of study participants into different exposed or unexposed groups (Estrela, 2018).

In 2021, Merchán-Hamann and Tauil proposed a subdivision for observational studies, dividing them into observational descriptive prevalence studies and observational descriptive incidence studies, which are characterized by involving the follow-up or monitoring of a population group aimed at investigating the occurrence of new outcomes for a

certain variable, such as in the case of the present study that works with incidence data of strokes over a certain period of time (Merchán-Hamann & Tauil, 2021).

The Datasus-Tabnet website provides data by the "List of Morbidity ICD-10," and for this study, the option "Cerebrovascular accident, unspecified as hemorrhagic or ischemic" corresponding to ICD-I64 was selected. The number of hospitalizations was analyzed, and comparisons were made with the number of deaths per year in each Brazilian region, in parallel with the increase in COVID-19 cases and their respective deaths.

Data on hospitalizations, number of deaths, and mortality rate from stroke in Brazil were collected on the Ministry of Health (MS) website "http://tabnet.datasus.gov.br/," as well as information regarding COVID-19, "https://infoms.saude.gov.br/extensions/COVID-19_html/COVID-19_html.html." The information provided by the MS is organized by period and location, following the description previously outlined in the methods of the study.

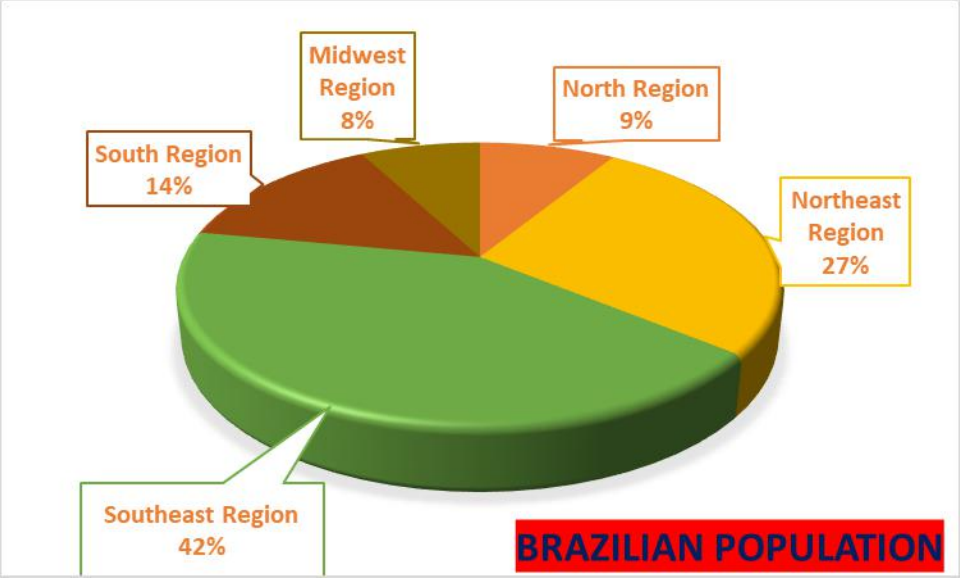
In Brazil, data related to the population's demographic census are provided by the Brazilian Institute of Geography and Statistics (IBGE) and published on the website https://www.ibge.gov.br. Typically, the Brazilian demographic census is conducted every 10 years. In 2020, it should have been carried out; however, due to the SARS-CoV-2 pandemic, it was extended, and as of the completion of this study, the results had not been disclosed. As the most recent data with absolute certainty refer to the year 2010, and the subsequent years are only projections made by other portals, the authors chose to use only the data for the year 2022, available from the Brazilian Ministry of Health on the website containing information related to COVID-19. For this reason, all population-related comparisons will be based on the Brazilian population of the year 2022, the data directly provided by the MS.

3. Results and Discussion

3.1 Incidence of Stroke

For the initial discussion, raw data separated by year and region were used. Firstly, the population of each region of the country (Southeast, Northeast, South, North, and Midwest) was specified, as shown in Figure 1. According to the data provided by the Ministry of Health (MS), the total Brazilian population at the end of 2022 was 210,147,125 people. Of this total, 16,297,074 people (8% of the total) were in the Midwest region, making it the least populous region. Next is the North region with 18,430,980 people, representing 9% of the total population. The South region comes in third, with 29,975,984 people, accounting for 14% of Brazilians. Finally, there is the Northeast region with 57,071,654 people, representing 27% of the population, and the Southeast region with its 88,371,433 inhabitants (42% of the total), making it the most populous region in Brazil.

Figure 1 - Distribution of the Brazilian population by region in 2022.



Source: Graph developed by the author with data from https://infoms.saude.gov.br/extensions/COVID-19_html/COVID-19_html.html.

In the year 2018, there were a total of 156,626 hospitalizations due to strokes in Brazil, and each region had its share of participation in this total, as shown in Figure 2. The North region was responsible for the smallest share, only 5% (8,288) of hospitalizations. A similar result was observed in the Midwest, where the region represented 6% (9,525) of the hospitalizations during the period. The South and Northeast regions contributed, respectively, 18% (27,863) and 28% (44,018) of the total stroke-related hospitalizations in Brazilian territory in 2018. In contrast, the Southeast was responsible for the majority of hospitalizations, with 43% (66,933) of the cases occurring in the region.

Relating the data showing the number of stroke-related hospitalizations by Brazilian region in the year 2018 to the Brazilian population distribution by region (Figure 1), it can be inferred that there is a proportion between the incidence of stroke cases and the size of the population in each region of Brazil. This is evident as none of the country's regions showed a disparity between these two metrics exceeding five percentage points.

In the year 2019, there were a total of 163,120 hospitalizations due to strokes, representing an increase of 6,494 cases, or 4%, compared to the previous year. Out of this total, 8,038 cases occurred in the North region (or 5% of the total), and in the Central-West region, there were 10,120 hospitalizations (6% of the cases). Next is the South region, accounting for 18% (29,859) of the hospitalizations. The Northeast region contributed 30% of the total (48,153) hospitalizations. The Southeast region emerged as the major contributor, representing 41% of the total, which corresponds to 66,950 hospitalizations. Except for the North region, all others experienced an increase in the number of hospitalizations, with the Southeast region undergoing a minimal change, thus maintaining stability in the number of cases.

Regarding the regional distribution, as depicted in Figure 2, stability was observed in the South, Central-West, and North regions. The Southeast region experienced a 2% decrease in 2019 compared to the year 2018, while the Northeast saw an increase in the same proportion. Correlating the data showing the number of stroke-related hospitalizations by Brazilian region in 2019 with the Brazilian population distribution by region (Figure 1), the assessment of a proportion between the incidence of stroke cases and the population size of each region in Brazil remained consistent, with no significant discrepancy greater than five percentage points.

In the year 2020, a total of 153,714 hospitalizations due to strokes were recorded in Brazil, representing a decrease of 9,406 cases (or 5.7%) compared to the previous year (2019). Regarding the number of hospitalizations by region, the North

region accounted for 5% of these cases (7,591 hospitalizations) in 2020. In the Central-West region, there were 9,950 hospitalizations, corresponding to 7% of the total. The South region contributed 28,292 hospitalizations (18%). The Northeast region, in turn, presented 27% of the cases (42,043 hospitalizations). Once again, the Southeast region accounted for the highest numbers, with 65,838 hospitalizations, representing 43% of the cases. As depicted in Figure 5, there was a decrease in the number of hospitalizations in all regions of the country compared to the previous year (2019).

However, when comparing the number of stroke-related hospitalizations in each Brazilian region in the years 2018 and 2020, it is evident that, except for the Central-West and South regions, where there was a slight increase in the number of hospitalizations for strokes in 2020, the other regions experienced a reduction in the quantity of hospitalizations. In this regard, the North region showed the highest reduction rate, with 697 fewer hospitalizations (corresponding to an 8.4% reduction), the Northeast region experienced a decrease of 1,975 cases (a reduction of 4.5%), and the Southeast region had a decrease of 1,095 cases, representing a 1.6% reduction in hospitalizations.

When analyzing the distribution of stroke-related hospitalization incidence by region in the year 2020, as shown in Figure 2, it is evident that the North and South regions maintained the percentage of hospitalizations presented in 2019 (Figure 4). On the other hand, the Central-West and Southeast regions showed a slight increase, 1% and 2% respectively, in this comparison. In contrast, the Northeast region experienced a 3% decrease in the number of stroke-related hospitalizations in 2020 compared to the previous year.

Correlating the data showing the number of stroke-related hospitalizations by Brazilian region in the year 2020 with the Brazilian population distribution by region (Figure 1), the assessment of a proportion between the incidence of stroke cases and the size of the population in each region of Brazil remained consistent, with no significant discrepancy greater than five percentage points. This same result is observed in the years 2018 and 2019.

Given that this work aims to assess a potential correlation between COVID-19 and the development of stroke in Brazil, it is necessary to examine the data from the COVID-19 pandemic in 2020, the year of the first recorded infection case in Brazil and the occurrence of a significant number of deaths associated with the disease. Initially, we will discuss only the number of cases of the disease in Brazilian territory. Following that, we will explore the quantity of deaths due to COVID-19 along with those resulting from strokes.

In the year 2020, a total of 7,675,973 cases of COVID-19 were recorded in Brazil. Of these, 859,150 (corresponding to 11% of cases) occurred in the North region. A similar quantity, 873,757 (11%) cases, occurred in the Central-West region. The Southern region contributed 18% (1,358,823) of positive COVID cases. Of the over 7 million cases of COVID-19 diagnosed in Brazilian territory, 1,896,157, or 25% of these, occurred in the Northeast, and 2,688,086, or 35% of cases, occurred in the most populous region of the country, the Southeast. Comparing the distribution of the population by region (Figure 1), it is evident that there is a difference in the incidence of COVID-19 per population in each region, as shown in Figure 3.

According to Figure 3, in 2020, when analyzing the most populous regions of the country, Northeast and Southeast, a proportionally lower incidence of COVID-19 than their population is evident. The Southeast region represents 42% of the total population of Brazil, while the incidence of COVID-19 cases represented only 35%. On the other hand, the Northeast region represents 27% of the population and had an incidence of only 25% of the total cases. In contrast, regions with smaller populations, Central-West, North, and South, showed a higher incidence than the proportion of their populations. In this regard, the Central-West region, representing the smallest share of the Brazilian population at only 8%, accounted for 11% of COVID-19 cases in 2020. Similarly, the North region, responsible for 9% of the population, had a total of 11% of cases, and the South region, responsible for 14% of the population, had an incidence of COVID-19 cases 4% above the population proportion, totaling 18% of cases.

As mentioned earlier, the North, Northeast, and Southeast regions showed a decrease in the number of stroke cases in 2020 compared to 2018, while the South and Central-West regions showed an increase in this comparison. It is noteworthy that in regions where the incidence of COVID-19 in 2020 was proportionally lower than the size of their population, there was also a decrease in the number of strokes compared to 2018. Conversely, in regions where the incidence of COVID-19 was proportionally higher than the population, there was an increase in the number of stroke cases in 2020 compared to 2018. However, the North region did not follow this pattern, as it had a higher incidence of COVID-19 than its population percentage and a decrease in the number of strokes in 2020 compared to 2018.

In 2021, the number of stroke hospitalizations rose again, with an increase of 8,308 cases, representing a 5.4% increase, reaching a total of 162,017 hospitalizations. Of these, 9,040 (6% of hospitalizations) were recorded in the North region; a similar quantity, 9,870 cases (the same 6%), was observed in the Central-West region. The South region accounted for 28,067 (17%) hospitalizations. In the Northeast region, there were 45,313 (28%) hospitalizations. The Southeast region was responsible for the largest share of stroke hospitalizations in 2021, contributing 43% of the total, equivalent to 69,727 hospitalizations. Analyzing the variation over the period, as shown in Figure 4, it is evident that the North, Northeast, and Southeast regions showed an increasing trend, while the Central-West and South regions showed discreet reductions. When considering the whole, there is a similarity with the year 2019 in raw values, but with a completely different distribution of cases across regions.

When considering the percentage breakdown of the number of stroke hospitalizations in Brazil in 2021, as shown in Figure 2, changes are observed in almost all regions, except for the most populous region of the country, which maintained its 43%. The South and Central-West regions experienced a 1% decrease compared to the year 2020, in contrast to the North and Northeast regions, which had an increase of 1% each.

Correlating the data from Figure 2, which illustrates the number of stroke hospitalizations by Brazilian region in the year 2021, with the Brazilian population distribution by region (Figure 1), the assessment of a proportion between the incidence of stroke cases and the size of the population in each region of Brazil has remained consistent. There is no dissonance greater than five percentage points, similar to the patterns observed in 2018, 2019, and 2020.

Regarding the COVID-19 pandemic in the year 2021, there were 14,611,548 new cases of the disease in Brazil, reaching a total of 22,287,521 accumulated cases since the beginning of the pandemic in 2020. The new cases were distributed as follows: 1,064,761 (7%) in the North region, 1,528,015 (10%) in the Central-West region, 2,990,131 (21%) in the South region, 3,053,939 (21%) in the Northeast region, and 5,974,702 (41%) cases in the Southeast, as shown in Figure 10. When comparing the percentage incidence of hospitalizations in 2021 (Figure 3) with the population distribution (Figure 1), a significant difference is observed in both the South and Northeast regions. The South region, representing 14% of the population, accounted for 21% of COVID-19 hospitalizations, and the Northeast region, representing 27% of the population, was responsible for 21% of hospitalizations, while the other regions did not show variations greater than five percentage points.

As observed in the previous year (2020), the two most populous regions continued to have a proportionally lower incidence of COVID-19 than their populations—41% in the Southeast and 21% in the Northeast—while their populations represent 42% and 27%, respectively, as illustrated in Figure 1. In 2021, the Southeast region had a difference of only 1% compared to its population, a common variation seen in various regions when discussing strokes. On the other hand, the Northeast region began to show a greater difference between these two comparisons. While it represents 27% of the population (Figure 1), it accounted for only 21% of COVID-19 cases in 2021 (Figure 3). In the previous year (2020), the three regions with the smallest populations showed a higher percentage of COVID-19 incidence than their populations. In 2021, however, a specific pattern did not follow. The North region, responsible for 9% of the population, had a proportionally lower number of

COVID-19 cases (7%). The Central-West region, with 8% of the total population, had a proportionally higher number (10%), and the South region followed the same trend as the previous year, maintaining a proportionally higher incidence than the population, but noteworthy for the increase to 21% of total COVID-19 cases (Figure 3), staying seven percentage points higher in incidence than its population, which represents only 14% of the total.

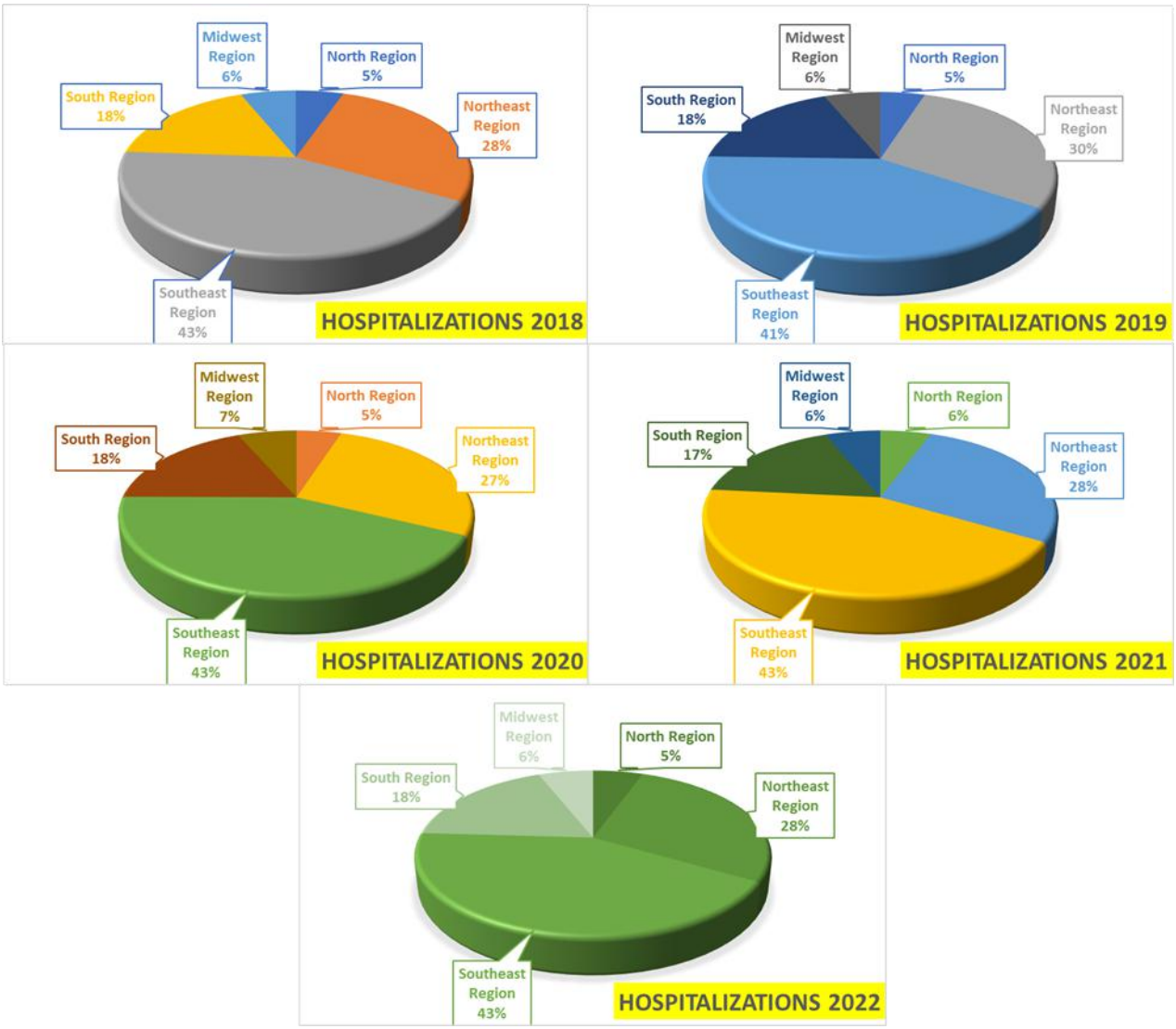
When comparing the number of stroke hospitalizations in the years 2018 and 2021, there was an increase in hospitalizations in all regions of the country in 2021. It is worth noting that in this comparison, the North and Southeast regions had the highest numbers of hospitalizations, 9,040 and 69,727, respectively, in the year 2021. In contrast, in the Central-West, South, and Northeast regions, the highest data were not observed in 2021 but rather in 2019. However, even in these three regions, there was an increase in the total number of strokes compared to the previous year (2020). In other words, the rise in the incidence of COVID-19 in Brazil coincided with an increase in the number of stroke cases in all regions of the country in the year 2021.

As shown in Figure 4, in the year 2022, there was an increase in the number of stroke hospitalizations in all regions of the country, recording the highest numbers in the analyzed period (2018 to 2022). In this context, a total of 184,254 stroke hospitalizations were registered in the country. Of these, the North region was responsible for 5% of hospitalizations, corresponding to 10,112 hospitalizations. In the Central-West region, there were 11,069 (6%) hospitalizations. In the South region, there were 33,296 cases, representing 18% of the total. The Northeast region accounted for 28% (51,475) of hospitalizations. Finally, in the Southeast region, there were 78,302 hospitalizations, accounting for 43% of the total. Considering the analyzed period (2018 to 2022), it's worth noting the interval between 2021 and 2022, where there was an increase of 12%, which is 22,237 new cases of strokes throughout the Brazilian territory.

Regarding the percentage distribution of stroke hospitalizations by region in 2022, the numbers remained stable compared to the previous year (2021). As shown in Figure 2, the only regions that showed changes were the South region, which gained 1%, and the North region, which lost 1%. It is noteworthy that the year 2022 presented a percentage graph by region identical to that of the year 2018, meaning the North region was responsible for 5% of the total stroke hospitalizations, the Central-West region for 6%, the South region for 18%, the Northeast region accounted for 28%, and the Southeast region for 43% of stroke hospitalizations. However, when checking the absolute numbers of hospitalizations in 2018 and 2022, it is noted that in 2018, there were 156,626 stroke hospitalizations, while in 2022, there were 184,254 hospitalizations; a difference of more than 20 thousand cases, corresponding to an increase of 15% compared to 2018.

Correlating the data showing the number of stroke hospitalizations by Brazilian region in the year 2022 (Figure 2) with the Brazilian population distribution by region (Figure 1), the assessment of a proportion between the incidence of stroke cases and the size of the population in each region of Brazil has remained consistent, with no dissonance greater than five percentage points, as observed in the previous four years of the study.

Figure 2 – Group of pictures that show the number of hospitalizations due to strokes by Brazilian region between 2018 and 2022.



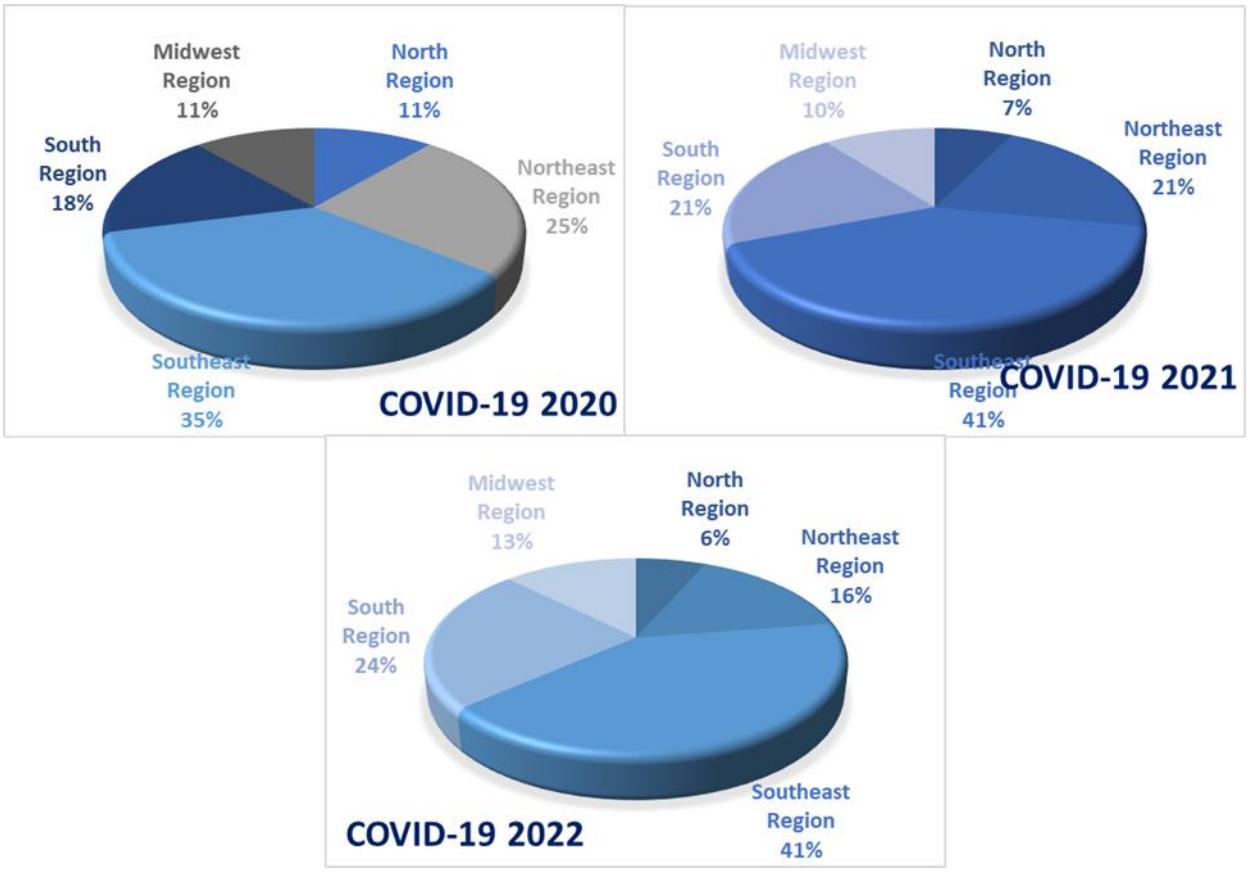
Source: Graph developed by the author with data from http://tabnet.datasus.gov.br/.

About COVID-19, in the year 2022, 14,043,760 new cases were recorded, accumulating a total of 36,331,281 cases since the beginning of the Sars-CoV-2 pandemic in 2020. The Northern region registered 915,664 cases, accounting for 6% of the total; the Central-West region reported 1,762,721 (13%) new cases; the Northeast region accounted for 2,256,903 (16%) diagnoses; in the Southern region, there were 3,363,983 (24%) reported cases, and in the Southeast region, 5,744,489 cases were registered, representing 41% of the total.

Regarding the percentage incidence of COVID-19 cases by region compared to the population distribution of Brazil, the discrepancies observed in previous years persisted in 2022. As shown in Figure 3, the two most populous regions of the country, Southeast and Northeast, maintained COVID-19 incidence percentages below the percentage of their populations (Figure 1). The Southeast region retained its 41% as observed in 2021, and the Northeast region experienced a percentage decrease for the third consecutive year, reaching only 16% of all COVID-19 cases registered in the country in 2022 (in 2021, it was 21%, and in 2020, it was 25% - close to the percentage of its population representing 27% of the total). The Northern region experienced a 1% decrease, reaching 6% of COVID-19 cases in Brazil in 2022. The Central-West region had a 3% increase, reaching 13% of cases in 2022. The Southern region continued the trend from previous years, with a 3% increase,

reaching a percentage of 24% of COVID cases, while its population represents only 14% of the total.

Figure 3 – Group of pictures that show the number of hospitalizations resulting from COVID-19 by Brazilian region between 2018 and 2022.

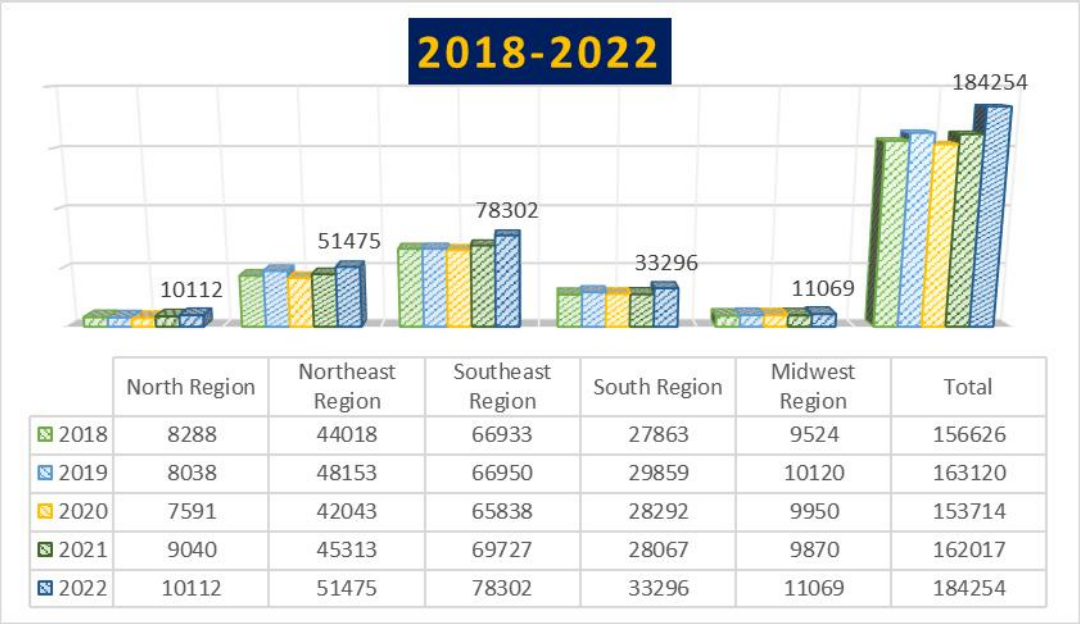


Source: Graph developed by the author using data from https://infoms.saude.gov.br/extensions/COVID-19_html/COVID-19_html.html.

Regarding the relationship between the percentage increase/decrease in COVID cases compared to the raw number of strokes (CVAs) hospitalizations, it was observed that in all regions, there was a substantial increase in the number of stroke cases - even in those where the incidence of COVID-19 was lower compared to 2021 (Figure 5) - with 2022 registering the highest numbers of strokes hospitalizations throughout the evaluated period in all five regions of the country (Figure 2).

Analyzing Figures 4 and 5, it is possible to infer a correlation between the high number of COVID cases and the increase in the number of stroke cases in 2022. However, in 2022, the increase was more explicitly observed than in the previous year (2021), as all five regions of the country presented the highest numbers of stroke cases since 2018.

Figure 4 – Comparison of Stroke Hospitalizations by Brazilian Region from 2018 to 2022.

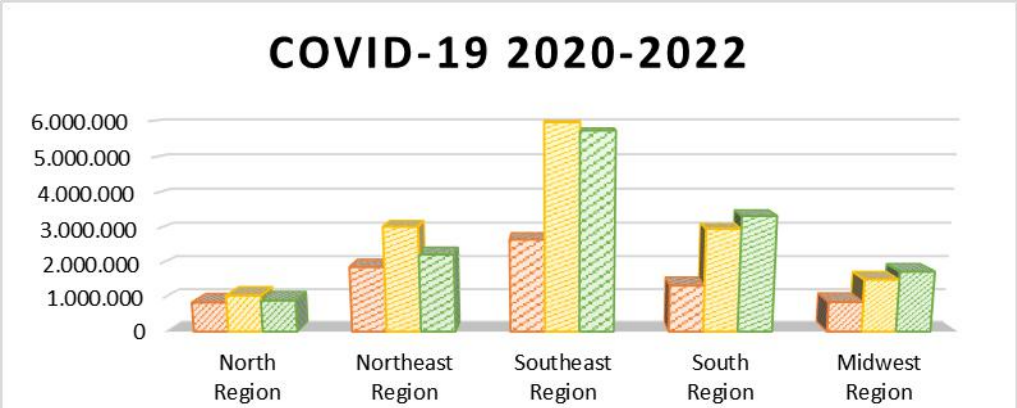


	North Region	Northeast Region	Southeast Region	South Region	Midwest Region	Total
2018	8288	44018	66933	27863	9524	156626
2019	8038	48153	66950	29859	10120	163120
2020	7591	42043	65838	28292	9950	153714
2021	9040	45313	69727	28067	9870	162017
2022	10112	51475	78302	33296	11069	184254

Source: Graph developed by the author with data from http://tabnet.datasus.gov.br/.

About the distribution of COVID-19 cases in Brazil, as shown in Figure 5, significant variations in patterns were observed for each region over the three years evaluated (2020 to 2022). In the Northern region – which exhibited lower variations during the period – there was an increase from 2020 to 2021, followed by a decrease of a similar scale in the subsequent year. In the Northeast region, there was an increase of over 40% between the first two years, and in 2022, a decrease of approximately 30%. In the Southeast region, there was an increase of over 100% from the first to the second year, and it remained relatively stable in the third year. The Southern region also showed an increase of over 100% from the first to the second year, and the increase persisted in the third year but to a lesser extent. The Central-West region exhibited a similar pattern to the Southern region, doubling the number of cases between 2020 and 2021, but the increase in the third year was proportionally smaller.

Figure 5 – Comparison of COVID-19 hospitalizations by Brazilian region from 2020 to 2022.



	North Region	Northeast Region	Southeast Region	South Region	Midwest Region
2020	859.150	1.896.157	2.688.086	1.358.823	873.757
2021	1.064.761	3.053.939	5.974.702	2.990.131	1.528.015
2022	915.664	2.256.903	5.744.489	3.363.983	1.762.721

Source: Graph developed by the author using data from https://infoms.saude.gov.br/extensions/COVID-19_html/COVID-19_html.html.

3.2 Stroke Mortality

Regarding the mortality data from stroke (Cerebrovascular Accident - CVA) in Brazil, in the first year of the present study (2018), there were a total of 23,719 deaths due to strokes across the country. Among these, 1,324 deaths (6% of the total) occurred in the Central-West region, 1,570 (7%) in the Northern region, 3,442 (14%) in the Southern region, 7,221 (30%) in the Northeast region, and 10,162 deaths (43% of the total cases) occurred in the Southeast region.

Analyzing the data showing the number of stroke hospitalizations by Brazilian region in the year 2018 (Figure 2) and the number of deaths due to strokes by Brazilian region in the same year (Figure 6), it can be inferred that there is a proportionality between the incidence of stroke cases and the number of deaths from the disease. Similarly, comparing the data from Figure 6, in 2018, with the distribution of the Brazilian population by region (Figure 1), it can be concluded that there is a proportionality between the number of deaths due to strokes and the population size of each region in Brazil. It is worth noting that none of the regions showed a disparity between these metrics exceeding five percentage points.

As illustrated in Figure 7, in the year 2019, there was an increase of 3.6% in the number of deaths from strokes in Brazil compared to the year 2018, reaching a total of 24,593 deaths. Of these, 1,418 (6% of the total) occurred in the Northern region, 1,421 (6%) in the Central-West region, 3,530 (14% of the total deaths) in the Southern region, 8,010 (33%) in the Northeast region, and 10,214 deaths (41% of the total deaths) occurred in the Southeast region, as can be observed in Figure 6. Only the Northern region showed a reduction in the total number of deaths compared to 2018 (Figure 7).

Correlating the data showing the number of stroke deaths by Brazilian region in the year 2019 (Figure 6) with the Brazilian population distribution by region (Figure 1), a proportionality between the incidence of stroke deaths and population size is evident, as previously mentioned. However, in the year 2019, while the population of the Northeast region accounts for 27% of the total population of Brazil, the incidence of stroke deaths in this region represented 33% of the total, a difference of six percentage points.

In the year 2020, a total of 23,474 deaths due to strokes were recorded, indicating a decrease of 1,119 deaths (4.8%) compared to the previous year. Of this total, the Northern region was responsible for 1,270 cases (5% of the total), the Central-West region had 1,308 deaths (6%), the Southern region recorded 3,452 deaths (equivalent to 15% of the total), the Northeast

region reported 7,379 deaths (31%), and the Southeast region accounted for 10,065 cases, representing 43% of the total stroke deaths in Brazil in the year 2020. As illustrated in Figure 7, in all regions of the country, there was a slight decrease in the number of stroke deaths in 2020 compared to the data from 2019. This same trend is observed in the number of stroke hospitalizations, as mentioned earlier.

Regarding the distribution of the incidence of stroke deaths by region in the year 2020, as shown in Figure 6, it can be observed that the Central-West region was the only region that maintained the percentage from the previous year (2019). The Northern region experienced a loss of one percentage point, and the Northeast region had a loss of 2%. In contrast, the Southern region gained one percentage point, and the Southeast region gained two percentage points.

Correlating the data showing the number of stroke deaths by Brazilian region in the year 2020 (Figure 6) with the Brazilian population distribution by region (Figure 1), the assessment of a proportionality between the incidence of stroke deaths and population size remained consistent, with no divergences exceeding five percentage points.

Considering that 2020 was the year of the first recorded case and the first death from COVID-19 in Brazil, it is important to discuss the data associated with the number of deaths due to the Sars-Cov-2 pandemic and its association with the number of deaths due to strokes. Therefore, in the year 2020, a total of 194,949 deaths due to COVID-19 were recorded in Brazil. Of these, 17,848 deaths (9% of the total) occurred in the Central-West region, 18,025 (9%) in the Northern region, 22,099 (11%) in the Southern region, 47,548 (25%) in the Northeast region, and 89,229 deaths (46% of the total deaths) occurred in the Southeast region, as illustrated in Figure 8.

Comparing the distribution of COVID-19 deaths in 2020 (illustrated in Figure 8) with the population distribution (Figure 1), it can be inferred that there is a correlation between the data, as no region showed a dissonance greater than 5%.

However, when comparing the distribution of COVID-19 hospitalizations with deaths from the disease in 2020, variations are noticeable among regions. In this regard, the Central-West and Northern regions each presented 11% of cases and 9% of deaths. The Northeast region accounted for 25% of both cases and deaths. The Southern region was responsible for 18% of cases and 11% of deaths due to Sars-Cov-2 in 2020. The Southeast region, on the other hand, had 35% of cases and accounted for 46% of the total deaths, a difference of eleven percentage points between the two metrics.

In the year 2021, there was an increase of 2,376 deaths (10% more) compared to the year 2020. Of these, the Central-West region was responsible for 1,440 deaths (6% of the total), the Northern region for 1,537 deaths (6%), the Southern region for 3,986 (15%), the Northeast region for 7,822 (30%), and in the Southeast region, there were 11,065 deaths, corresponding to 43% of the total stroke deaths in 2021. Comparing the number of stroke deaths by Brazilian region from 2018 to 2021, it is evident that three regions, Central-West, South, and Southeast, had the highest raw values of deaths in 2021, as observed in Figure 7.

Considering the percentage indices of the number of deaths due to strokes by region in the country in 2021, as illustrated in Figure 6, stability is observed in relation to the data from the year 2020. Given that the Central-West, South, and Southeast regions maintained the percentages from 2020, the Northern region gained one percentage point, and the Northeast region lost one percentage point.

Correlating the data regarding the number of deaths due to strokes by Brazilian region in the year 2021 (Figure 6) with the Brazilian population distribution by region (Figure 1), the proportion remained as in previous years, with no divergences exceeding five percentage points.

In 2021, a total of 424,107 new cases of COVID-19 deaths were recorded in Brazil, reaching a cumulative total of 619,056 deaths since the beginning of the pandemic – an increase of approximately 118% compared to the previous year. Of these fatalities, 29,523 occurred in the North region, representing 7% of the total deaths; 41,463 (10%) occurred in the Midwest region; 72,271 deaths (17%) took place in the Northeast region; in the South region, there were 75,420 deaths (18%);

and in the Southeast region, 205,430 deaths occurred, accounting for 48% of the total deaths due to COVID-19 in 2021, as can be seen in Figure 8.

Comparing the number of COVID-19-related deaths by Brazilian region in 2021 (Figure 8) with the population distribution (Figure 1), it is observed that the Southeast and Northeast regions showed variations greater than 5% between the two metrics. The Southeast region, responsible for 42% of the population, had 48% of the deaths, a dissonance of six percentage points. The Northeast region, representing 27% of the population, accounted for 17% of the deaths due to COVID-19 in 2021, a dissonance of ten percentage points.

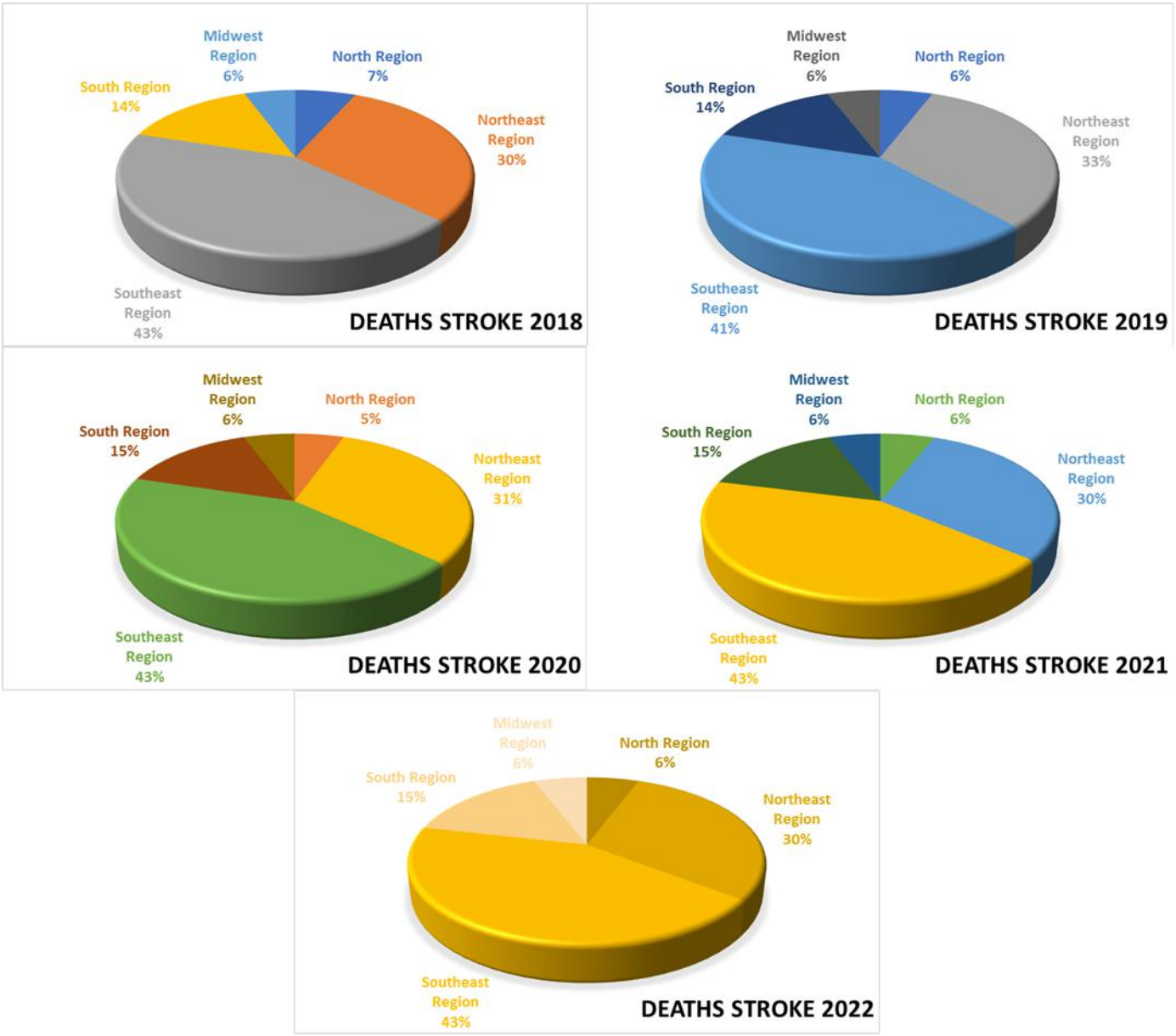
When correlating the number of COVID-19-related deaths by Brazilian region in 2021 with the incidence of COVID-19 cases by region in the same year, a dissonance of seven percentage points is observed in the Southeast region. This is because the Southeast represented 41% of COVID-19 cases in 2021 but accounted for 48% of the total deaths in the year. The other regions did not experience variations exceeding five percentage points between the two aforementioned metrics.

In 2022, there was an increase of 1,689 deaths compared to 2021, or a 6% rise, reaching a total of 27,539 deaths due to strokes in Brazil. Of these, the North region was responsible for 1,567 or 6%, the Midwest for 1,596 or 6%, the South for 4,309 or 15%, the Northeast for 8,203 or 30%, and the Southeast for 11,864 or 43% of the total stroke-related deaths in Brazil in 2022. Analyzing the variation over the entire study period, from 2018 to 2022, it is noticed that four out of the five regions presented the highest raw values of deaths in 2022 – the Midwest, South, Northeast, and Southeast - and the North region had a higher raw value in 2018 than in 2022 but with a difference of only 3 deaths between the two years (in 2018, there were 1570 deaths, and in 2022, there were 1567 deaths in the North region), as can be seen in Figure 7. Compared to the previous year, 2021, all five regions showed an increase.

When considering the percentage indices of the number of deaths due to strokes by region in the country in 2022, stability is observed compared to the year 2021. All five regions maintained the same percentage distribution as the previous year.

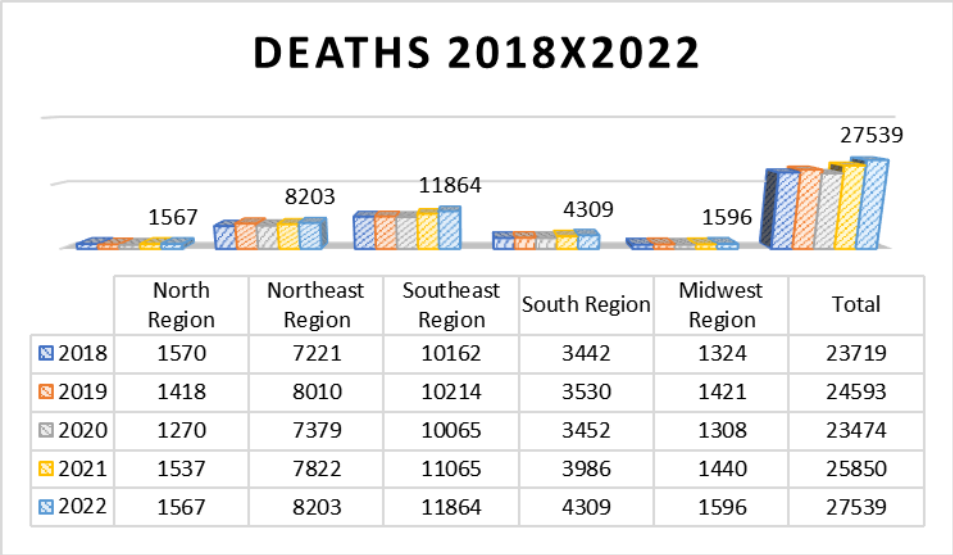
Correlating the data related to the number of stroke-related deaths by Brazilian region in 2022 (Figure 6) with the Brazilian population distribution by region (Figure 1), the proportion remained consistent with previous years, without divergences exceeding five percentage points. This is consistent with the situation in 2021, as there were no changes in the percentage distribution.

Figure 6 – Group of pictures that show the number of deaths from strokes by Brazilian region between 2018 and 2022.



Source: Graph developed by the author with data from http://tabnet.datasus.gov.br/.

Figure 7 – Comparative of stroke deaths by Brazilian region from 2018 to 2022.

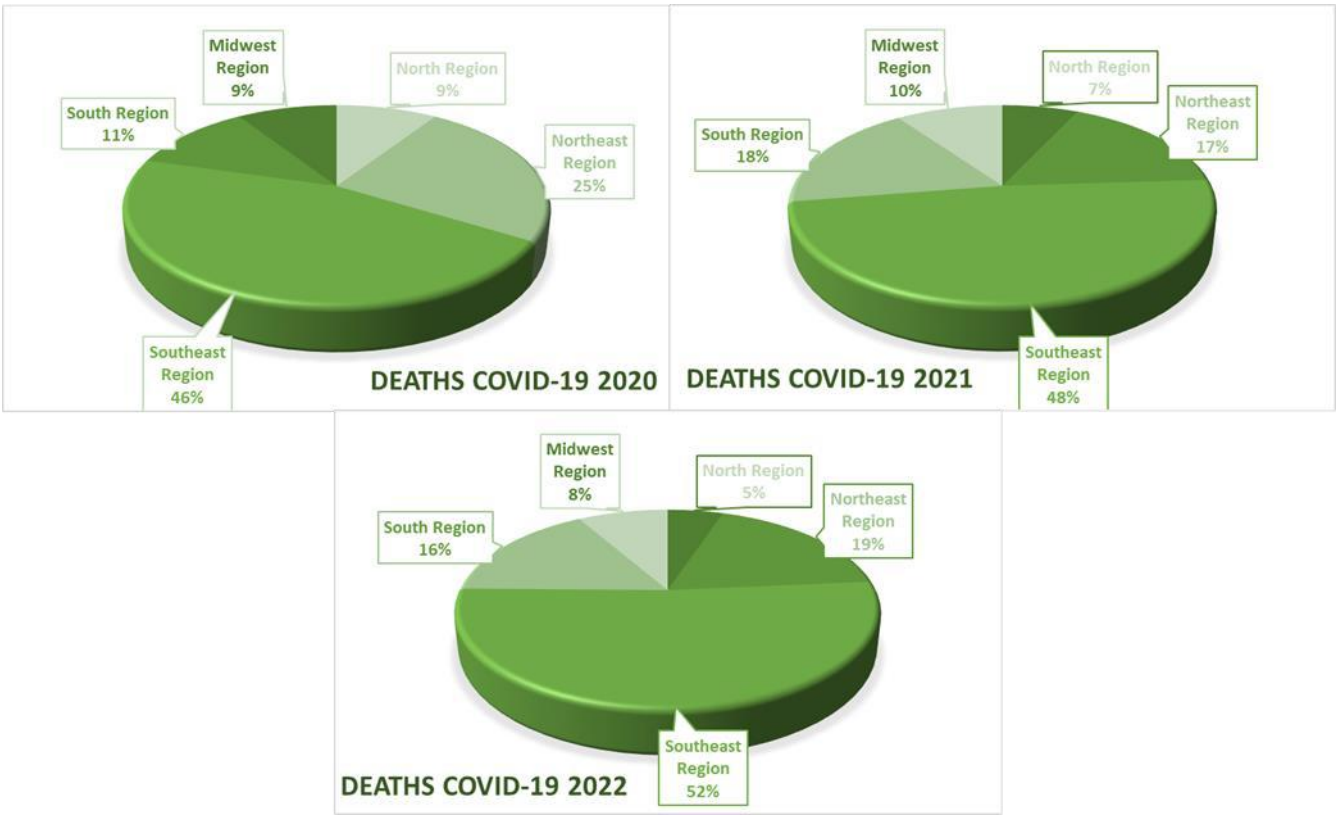


	North Region	Northeast Region	Southeast Region	South Region	Midwest Region	Total
2018	1570	7221	10162	3442	1324	23719
2019	1418	8010	10214	3530	1421	24593
2020	1270	7379	10065	3452	1308	23474
2021	1537	7822	11065	3986	1440	25850
2022	1567	8203	11864	4309	1596	27539

Source: Graph developed by the author with data from http://tabnet.datasus.gov.br/.

In 2022, a total of 74,797 new deaths due to COVID-19 were registered in Brazil, accumulating a total of 693,853 deaths since the beginning of the pandemic – a decrease of approximately 82% compared to the year 2021. Among these new deaths, 3,815 occurred in the North region, representing 5% of the total deaths; 6,211 or 8% occurred in the Midwest region; 12,290 or 16% occurred in the South region; 13,810 (19%) occurred in the Northeast region, and 38,671 occurred in the Southeast region, accounting for 52% of the total deaths due to COVID-19 in 2022, as can be seen in Figure 8.

Figure 8 – Group of pictures that show the number of deaths due to COVID-19 by Brazilian region between 2018 and 2022.



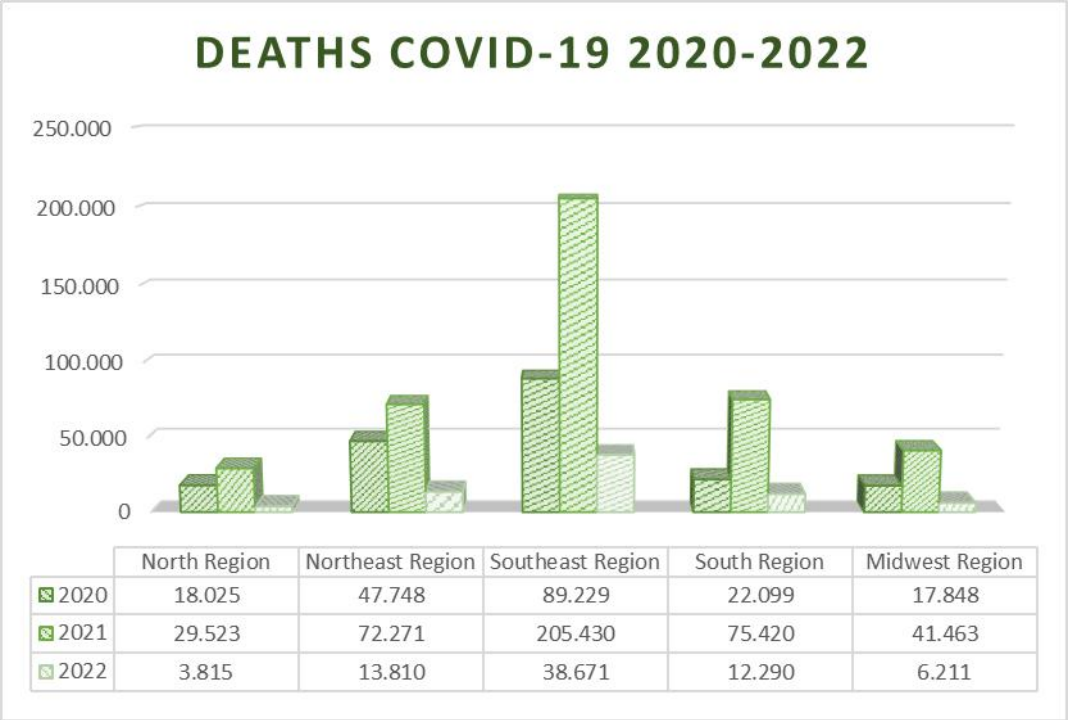
Source: Graph developed by the author using data from https://infoms.saude.gov.br/extensions/COVID-19_html/COVID-19_html.html.

Comparing the number of COVID-19-related deaths by Brazilian region in 2022 (Figure 8) with the population distribution (Figure 1), it is once again observed that the Southeast and Northeast regions showed variations exceeding 5% between the two metrics, similar to 2021. The Southeast region, responsible for 42% of the population, had 52% of the deaths, a dissonance of ten percentage points. The Northeast region, representing 27% of the population, accounted for 19% of the deaths due to COVID-19 in 2022, a dissonance of eight percentage points.

When correlating the number of COVID-19-related deaths by Brazilian region in 2022 with the incidence of COVID-19 cases by region in the same year, a dissonance of eleven percentage points is observed in the Southeast region, and in the South region, there is a dissonance of eight percentage points. The Southeast represented 41% of COVID-19 cases in 2022 but accounted for 52% of the total deaths in the year. The South region, on the other hand, had the highest percentage of COVID-19 cases, totaling 24% of the total in 2022, but in relation to deaths, it was responsible for 16% of the total. The other regions did not experience variations exceeding five percentage points between the two aforementioned metrics.

As can be inferred from Figure 9, there were significant changes in the number of COVID-19 deaths during the study period. The Southeast region maintained the highest numbers in all three years evaluated. The Northeast region had the second-highest numbers of deaths in 2020 and 2022, while in 2021, the second-place was occupied by the South region with a total of 75,420 deaths in that period. In contrast, the North region had the lowest numbers in 2021 and 2022, and in 2020, the region with the fewest deaths due to COVID-19 was the Midwest region. Considering the final values for the three years of the study related to deaths due to Sars-Cov-2 – 2020 to 2022 – there were a total of 51,363 deaths in the North region, 65,522 deaths in the Midwest region, 109,809 deaths in the South region, 133,829 deaths in the Northeast region, and 333,330 deaths in the Southeast region. Therefore, over these three years, a total of 693,853 deaths occurred in Brazil due to COVID-19.

Figure 9 – Comparison of COVID-19 deaths by Brazilian region from 2020 to 2022.



	North Region	Northeast Region	Southeast Region	South Region	Midwest Region
2020	18.025	47.748	89.229	22.099	17.848
2021	29.523	72.271	205.430	75.420	41.463
2022	3.815	13.810	38.671	12.290	6.211

Source: Graph developed by the author using data from https://infoms.saude.gov.br/extensions/COVID-19_html/COVID-19_html.html.

4. Conclusion

In summary, this study highlights intrinsic correlations between the incidences of Stroke (CVA) and COVID-19 in

Brazil from 2018 to 2022. Throughout this study, there was a noticeable increase in the number of stroke cases and deaths in Brazil during the period when the country faced the COVID-19 pandemic. The highest numbers observed for both metrics were in 2022, during the Sars-Cov-2 pandemic. When compared to the baseline year of the study, 2018, there was an increase of more than ten percentage points in all regions for both metrics. Thus, it emphasizes the need for more studies to be published in this field, as it is essential to observe whether these trends will persist over the years or if, at some point, the incidences will return to pre-pandemic levels.

For future work, research, and articles, we suggest a more intrinsic analysis of the variations observed in stroke incidences over time, considering longer and more distant periods from pandemic peaks. That is, long-term studies to assess whether variations remain stable or return to previous levels. Additionally, it is important to investigate how public health interventions can impact the reduction of stroke incidence and/or mortality over time, after the measures have been implemented. Furthermore, we emphasize the importance of thoroughly exploring possible relationships between socioeconomic factors and the studied disease. This may suggest the implementation of preventive measures in more susceptible areas and locations, enabling the improvement of prevention strategies.

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