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ARTICLE

Spatial and temporal distribution of hospitalizations due to malnutrition in the state of Rio Grande Do Sul between 2015 and 2023

Isadora Sodré Leonardi [*1], Ana Lucia Souza Silva Mateus[1], Adriano Mendonça Souza[1] and Luciane Flores Jacobi[1]

[1]Department of Statistics, Federal University of Santa Maria, Rio Grande do Sul, Brazil
[*]Corresponding author. Email: isadora.leonardi@gmail.com;

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Abstract

Malnutrition is defined as an imbalance in energy and nutrient intake and remains a major public health concern, particularly among children and older adults. This study aimed to analyze the spatial and temporal distribution of hospitalizations due to malnutrition in the municipalities of Rio Grande do Sul between 2015 and 2023. This cross-sectional research used data from the Hospital Information System (SIH/SUS) available on the DataSUS platform, totaling 20,799 hospitalizations. Descriptive statistics, Global and Local Moran's I, and cartographic techniques were applied using R software, enhancing spatial comparability across municipalities by incorporating population-adjusted hospitalization rates. The results showed a progressive decline in hospitalizations over the study period; however, older adults remained the most affected group, particularly those admitted through urgent and emergency care services. Adjusted rates revealed marked regional disparities, with municipalities such as Lavras do Sul and Aceguá presenting the highest values. Despite the overall reduction in hospitalizations, persistence in specific areas reflects underlying socioeconomic inequalities. Spatial analysis indicated positive but weak spatial autocorrelation, with higher rates concentrated in the southwestern and western regions, where high–high and low–high clusters were identified. The findings underscore the need for strengthened and regionally tailored public policies to reduce malnutrition and address persistent structural vulnerabilities. Prioritizing municipalities with higher hospitalization rates and socioeconomic disadvantage is essential to mitigate disparities and improve nutritional health. By integrating spatial analysis with population-adjusted indicators, this study provides an evidence-based framework that can guide more effective and equitable public health planning in Rio Grande do Sul.

Keywords: Undernutrition; Hospitalization; Statistical data analysis; Geographical data; Moran's index.

1. Introduction

Malnutrition occurs when there are deficiencies, excesses, or imbalances in a person's energy and/or nutrient intake. It can manifest as undernutrition, which includes weight loss, stunted growth, and low weight-for-age, or as micronutrient-related malnutrition, characterized by a lack or excess of vitamins or minerals. Malnutrition may also manifest as overweight, obesity, and diet-related noncommunicable diseases (WHO, 2021). Importantly, malnutrition is recognized as a multidimensional phenomenon whose origins extend far beyond insufficient dietary intake.

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According to FAO *et al.* (2024), its determinants include limited access to safe, diverse, and nutritious foods; inadequate sanitation, clean water, and health services; and broader sociopolitical and economic structures that shape living condition. This scenario highlights the complexity and breadth of the issue, affecting different population groups and contexts.

The older adults show a high prevalence of malnutrition, especially in hospital settings. Leij-Halfwerk *et al.* (2019) point out that about one quarter of Europeans over the age of 65 are malnourished or at risk of malnutrition. Factors such as frailty, low food intake, chronic diseases, and socioeconomic conditions, as noted by Faria and Costa (2022), contribute to this situation. Thus, there is a need to strengthen care for this population and to implement strategies that promote healthy aging, expanding the efforts already observed among other vulnerable groups.

A study conducted with ICU patients (Franco *et al.*., 2023) demonstrated that malnutrition significantly increases the risk of death, with moderate and severe cases associated with 2.61- and 2.91-fold higher odds of mortality, respectively. Older adults constitute a particularly vulnerable group due to factors such as comorbidities and age-related physiological changes. In Brazil in the 1990s, malnutrition was frequent among poorer groups, mainly affecting children. Between 1996 and 2006, there was a significant reduction in child malnutrition rates: chronic malnutrition fell by 50%, and overall malnutrition affected only 1.5% of children. However, this improvement was not uniform across the population (UNICEF, 2018). The research reinforces that early diagnosis is crucial, allowing for nutritional interventions that can reverse the condition.

In Brazil, Martins *et al.* (2021) identified a significant reduction in malnutrition rates between 2000 and 2016, especially among children and vulnerable groups, reflecting socioeconomic advances and public policies. Programs such as *Bolsa Família*, which improved household income and reduced food insecurity, and interventions in sanitation, which promoted public health and environmental protection, played a key role in this decline, according to Souza and Heller (2021). However, the data also show that major challenges remain, such as food insecurity, which directly affects the nutritional vulnerability of many families.

Aligned with the Sustainable Development Goals (SDGs), particularly SDG 2, which aims to end hunger, ensure food security, improve nutrition, and promote sustainable agriculture by 2030 (UN, 2023), this issue remains highly relevant in the current Brazilian context. Food insecurity is characterized by a lack of full and continuous access to adequate food, manifesting in its most severe form as hunger. According to the 2nd National Survey on Food Insecurity in Brazil, conducted by Rede Penssan (2022), 47.6% of the population of Rio Grande do Sul faces some degree of food insecurity. Of this total, 22.2% are in mild food insecurity, 11.3% moderate, and 14.1% severe, underscoring the seriousness of the issue in the state and the urgent need for measures to ensure food security. In light of these data, it is essential to adopt tools that help better understand the malnutrition scenario in the region.

Statistical methods are fundamental instruments for detecting changes in different types of processes (Zanini *et al.*, 2016). Among them, spatial statistics is a crucial tool in health and epidemiology, allowing for the mapping of the spatiotemporal distribution of diseases, identification of vulnerable areas, and support for strategic decision-making. During the COVID-19 pandemic, its use was essential to guide prevention policies in the most affected regions (Figueiredo, Ribeiro, & Santos, 2020). In the case of malnutrition, which reflects socioeconomic, demographic, and health factors, spatial statistics has been fundamental in identifying geographic patterns and guiding public policies. Studies such as those by Marques (2020) and Nascimento (2022) emphasize its application in analyzing health problems related to socioeconomic and environmental conditions.

Despite advances in national studies on nutritional disparities, spatial analyses of hospital malnutrition in Rio Grande do Sul remain limited. Understanding its spatial distribution is therefore essential for developing effective and targeted interventions. In this context, this study aims to identify spatial and temporal patterns in hospitalization rates due to malnutrition in the municipalities of Rio Grande do Sul between 2015 and 2023, as well as to highlight municipalities that require priority attention from local and regional managers to reduce these rates. Based on these objectives, the research question is: What are the spatial and temporal patterns of malnutrition-related hospitalization rates in the municipalities of Rio Grande do Sul between 2015 and 2023, and which areas should be prioritized by local and regional managers for targeted interventions?

2. Material and Methods

2.1 Study area

The state of Rio Grande do Sul (RS) is located in the southern region of Brazil and borders the state of Santa Catarina, Argentina, Uruguay, and the Atlantic Ocean. With a total area of 281,707.150 km², the state is composed of 497 municipalities, with Porto Alegre as its capital. According to the 2022 Census, its population is 10,882,965 inhabitants, resulting in a population density of 38.63 inhabitants per km². Figure 1 shows the map of RS.

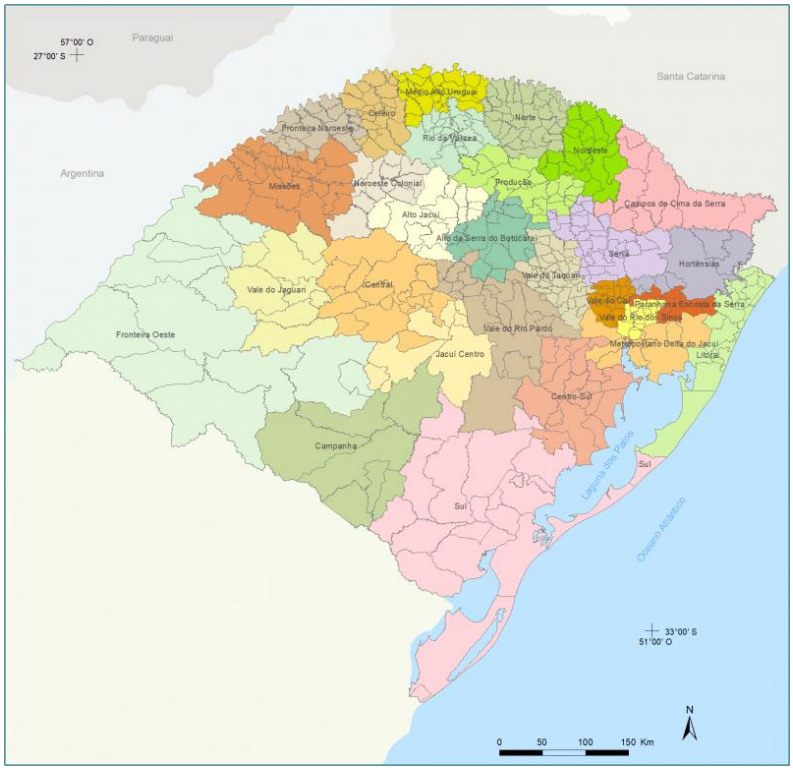


Figure 1. Map of the state of RS. Data source: Socioeconomic Atlas of Rio Grande do Sul.

With regard to the socioeconomic profile of Rio Grande do Sul, the state reported a GDP per capita of R$ 62,941. In 2021, its Human Development Index (HDI) reached 0.771, according to IBGE estimates. The 2022 edition of the Social Indicators Synthesis (IBGE) indicated that 44.1% of the population had a per capita household income of up to one minimum wage, whereas 44.4% fell within the range of one to three minimum wages. In 2024, the state's Gini Index was estimated at 0.460, suggesting a moderate degree of income inequality. Furthermore, data from the Department of Economics and Statistics (DEE) revealed that, in 2020, only 33.5% of the population had access to sewage treatment services.

2.2 Variables

This study is defined as a cross-sectional research, using the database available on the DataSUS portal (https://datasus.saude.gov.br/transferencia-de-arquivos/), with information extracted from the Hospital Information System of the Brazilian Unified Health System (SIHSUS). The data cover the period from January 2015 to December 2023, with monthly frequency, and were specifically selected for the Federative Unit of Rio Grande do Sul (RS).

The files provided by DataSUS are in .dbc format. For decompression, the Tabwin software was used, which converted them into .dbf format. Subsequently, the data were transferred to .xlsx format with the aid of SPSS software.

In Excel, data were filtered based on the main hospitalization diagnosis, using the 10th International Classification of Diseases (ICD-10), specifically for malnutrition (codes E40 to E46). After this filtering, a total of 20,799 hospitalizations due to malnutrition were identified between 2015 and 2023. It is noteworthy that all municipalities were included in the analysis, even those with no hospitalizations for malnutrition recorded during the study period.

The analyzed variables included: year of processing of the Hospital Admission Authorization (AIH); patient's municipality of residence; sex (female or male); age, grouped into three categories (youth: up to 19 years; adults: 20 to 59 years; older adults: 60 years or older); occurrence of death (yes or no); type of hospitalization (elective or urgent/emergency); bed specialty (general medicine or others); and length of stay (zero days, 1–5 days, 6–10 days, 11–20 days, and more than 20 days).

2.3 Hospitalization Rate and Descriptive Statistics

The hospitalization rate was calculated by relating the total number of hospitalizations due to malnutrition in a given year to the resident population in the same region and period, standardized per 1,000 inhabitants. The calculation considered the annual count of hospitalizations per municipality and its respective population. For the year 2023, population data from the 2022 Demographic Census were used; for the other years, intercensal population estimates available in the IBGE Automatic Recovery System (SIDRA) were adopted.

$$Rate = \frac{Number\ of\ hospitalizations}{Total\ Population\ of\ the\ year} \times 1000 \quad (1)$$

For quantitative variables, measures of position (minimum, median, mean, and maximum) and quartiles (1st and 3rd) were calculated. For qualitative variables, absolute and relative frequency tables were prepared. In addition, an association test was performed between the three age classes and the patient's year of hospitalization.

2.4 Spatial Statistics

The maps were created based on the shapefile of the state of Rio Grande do Sul, obtained from the Brazilian Institute of Geography and Statistics (IBGE) portal. Thematic maps were produced in RStudio using the packages: *"ggplot2"* (Wickham, H., 2016), *"sf"* (Pebesma *et al.*., 2018), *"spdep"* (Bivand & Wong, 2018), *"SpatialEpi"* (Kim *et al.*., 2018), *"ggspatial"* (Dunnington, 2023), *"maps"* (Becker, 2023), *"grid"* (Murrell, 2015), and *"tmap"* (Tennekes, 2018).

To analyze the spatial autocorrelation of hospitalizations due to malnutrition in the municipalities of Rio Grande do Sul, the following techniques were applied: Global Moran's Index (Moran, 1948); graphical and cartographic visualization of Moran's Index, referred to as Moran Scatterplot (Anselin, 1996); and Local Moran's Index (LISA) (Anselin, 1994).

It is worth noting that, for the analysis of spatial autocorrelation, the spatial neighborhood

structure among the municipalities of the state must be taken into account, as this determines the spatial dependence structure of the stochastic process. To construct this structure, the state is considered to be composed of n disjoint areas $\{W_1, \ldots, W_n\}$ and a binary n *x* n spatial weights matrix, denoted by $\boldsymbol{W}$, is built with elements w_{ij} that indicate the degree of spatial proximity between areas W_i and W_j, where $w_{ij} = 1$ if areas W_i and W_j share a common border, and $w_{ij} = 0$, otherwise (SCALON, 2024). For this study, the *k*-nearest neighbors matrix was used, considering $w_{ij} = 1$, if the centroid of area W_j is among the k nearest centroids to that of area W_i and $w_{ij} = 0$, otherwise.

The Global Moran's I test assesses spatial autocorrelation, that is, it verifies whether similar values of a variable tend to cluster spatially. According to Wikle, Zammit-Mangion, and Cressie (2019), it is a weighted form of Pearson's correlation coefficient, using spatial proximity weights ranging from -1 to 1. Positive values indicate similarity among neighboring regions, while negative values indicate differences. Values close to zero suggest the absence of spatial autocorrelation. The estimator of Moran's $\hat{I}$ teste is given by:

$$\hat{I} = \frac{n}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\right)} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(z_i - \bar{z})(z_j - \bar{z})}{\left(\sum_{i=1}^{n}(z_j - \bar{z})^2\right)}, \quad (2)$$

where n is the number of municipalities in the study region; z_i is the hospitalization rate in area i; z_j is the hospitalization rate in area j; $\bar{z}$ is the spatial mean of hospitalizations across the entire state ($\bar{z} = (1/m)\sum_{i=1}^{m} z_i$) and w_{ij} are the elements of the row-standardized spatial proximity matrix. The null hypothesis represents spatial independence, which is expressed as [I = 0]. Values > 0 indicate direct (positive) autocorrelation, while values < 0 indicate inverse (negative) autocorrelation.

Moran's autocorrelation can be represented through the Moran Scatterplot, which is interpreted based on four quadrants. Quadrants Q1 (positive values and positive means) and Q2 (negative values and negative means) indicate positive spatial association, that is, locations whose values are similar to those of their neighbors. On the other hand, quadrants Q3 (positive values and negative means) and Q4 (negative values and positive means) indicate negative spatial association, characterizing locations whose values differ from those of their neighbors.

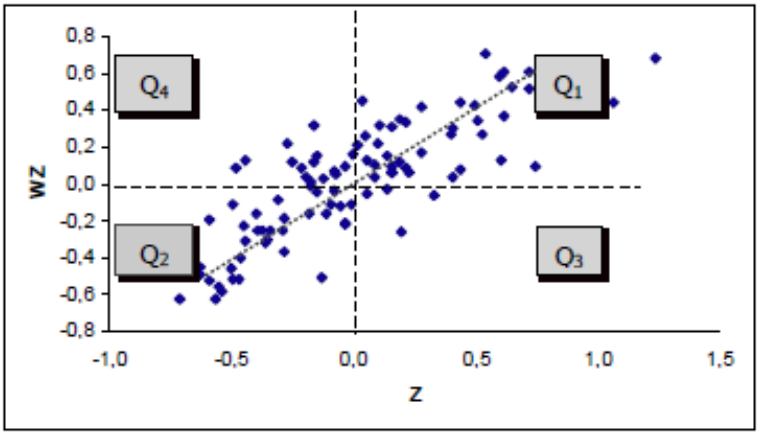


Figure 2. Quadrants of the Moran Scatterplot. Data source: Câmara *et al.* (2004).

To assess local spatial dependence, Local Indicators of Spatial Association (LISA) were used, providing an indication of the extent of significant spatial clustering of values around each observation (Anselin, 1994). According to Maia *et al.* (2018), the application of LISA was essential to highlight critical regions, in which municipalities with high incidence rates exhibit positive spatial correlation. The estimator of the local Moran's spatial autocorrelation index (i) for the i-th municipality ($\hat{I}_i$) is given by:

$$\hat{I}_i = \frac{(z_i - \bar{z}) \sum_{j=1}^{n} w_{ij}(z_j - \bar{z})}{\sum_{j=1}^{n} w_{ij}(z_j - \bar{z})} \quad (3)$$

where n is the number of municipalities in the region under study; z_i is the hospitalization rate in the *i-th* municipality; $\bar{z}$ is the spatial mean of hospitalizations across the entire state $\bar{z} = (1/m) \sum_{i=1}^{m} z_i$); z_j is the hospitalization rate in the *j-th* municipality; and w_{ij} are the elements of the row-standardized spatial weights matrix.

Analogously to the global Moran's index, the local index is also not strictly limited to the range [-1, 1]; however, its value deviates from zero as the degree of autocorrelation (positive or negative) increases (Scalon, 2024).

After analyzing the statistical significance of the local Moran's Index, two thematic maps were created: the cluster map (Figure 7) and the significance map (Figure 6). The cluster map identifies municipalities with locally significant spatial correlation according to the quadrants. The significance map, in turn, uses a two-tailed test, in which the null hypothesis (absence of spatial autocorrelation) is tested against the alternative hypothesis (presence of positive or negative spatial autocorrelation).

This study was not submitted to the Ethics Committee, as it used exclusively publicly accessible data available for open consultation. All statistical analyses were performed in R software (version 4.4.1; R Core Team, 2024), with a significance level of 5% adopted for all inferential procedures.

3. Results

The year 2016 stood out for recording the highest number of hospitalizations (n = 3,002; 14.4%), followed by a trend of decreasing hospitalizations due to malnutrition in recent years. Most hospitalizations involved older adults patients (n = 13,258; 63.7%), males (n = 11,195; 53.8%), urgent/emergency cases (n = 18,704; 89.9%) in the medical clinic (n = 18,778; 90.3%), patients who did not die (n = 17,079; 82.1%), and those who stayed from 1 to 5 days (n = 11,139; 53.6%). These and other details can be seen in Table 1.

A histogram of the age variable (Figure 3) was created for better visualization of its distribution. Based on the calculation of descriptive measures, the mean age was 61.0 years, the median was 68 years (ranging from 0 to 99 years), the first quartile was 50 years, and the third quartile was 80 years.

Table 1. Distribution of hospitalizations due to malnutrition by year, age, sex, death, type of hospitalization, and length of stay, from 2015 to 2023 in RS

Variables	Number of hospitalizations (n=20799)	Percent
Year		
2015	2961	14.2%
2016	3002	14.4%
2017	2308	11.1%
2018	2562	12.3%
2019	2434	11.7%
2020	1979	9.5%
2021	1756	8.4%
2022	1745	8.4%
2023	2052	9.9%
Age		
Young (19 years or younger)	2292	11.0%
Adults (20 to 59 years)	5249	25.2%
Older adults (60 years or older)	13258	63.7%
Gender		
Male	11195	53.8%
Female	9604	46.2%
Death		
No	17079	82.1%
Yes	3720	17.9%
Type of hospitalization		
Elective	2095	10.1%
Emergency/urgent	18704	89.9%
Ward specialty		
Internal medicine	18778	90.3%
Other	2021	9.7%
Length of stay		
0 days	256	1.2%
1 - 5 days	11139	53.6%
6 - 10 days	5159	24.8%
11 - 20 days	2676	12.9%
More than 20 days	1569	7.5%

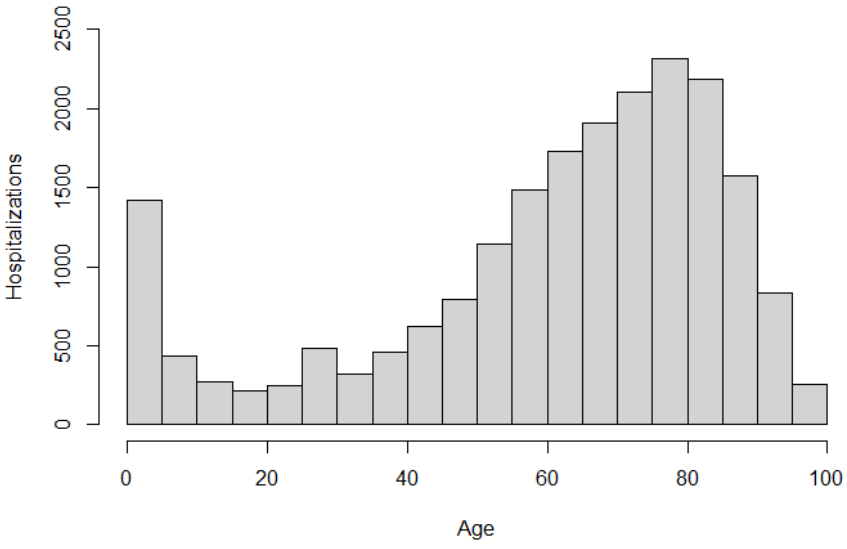


Figure 3. Histogram of patients' ages.

Table 2 presents the results of the chi-square test assessing the association between age groups and the analyzed years. The obtained *p*-value was lower than 0.05, indicating statistical evidence to reject the null hypothesis of independence between the variables. Thus, it can be concluded that there is a significant association between age groups and years of hospitalization, meaning that the distribution of hospitalizations among age categories varied throughout the analyzed period.

To deepen the interpretation, standardized residuals were analyzed to identify which year–age group combinations most contributed to the observed association. Absolute values greater than 1.96 were considered statistically significant. In this context, adults in 2016 and 2022, as well as young individuals in 2015, 2021, and 2023, stood out. Conversely, residuals for the older adults group did not show significant differences, suggesting a more stable distribution of hospitalizations in this age group over the period.

Table 2. Table of the association between age groups and patients' year of hospitalization

	2015	2016	2017	2018	2019	2020	2021	2022	2023	p-value
Adults	797	873(+)	597	599	571	497	423	394(-)	498	
Young	264(-)	296	239	284	268	211	226(+)	219	285(+)	<0.001
Older adults	1900	1833	1472	1679	1595	1271	1107	1132	1269	

(+) significant positive adjusted residual; (–) significant negative adjusted residual.

To facilitate the visualization of hospitalizations due to malnutrition in each municipality, thematic maps of the state of Rio Grande do Sul were used, highlighting areas with different hospitalization rates over the analyzed period. The rates were adjusted according to the populations of each municipality, allowing a more accurate representation of reality. This adjustment enabled the comparison of rates over the years, revealing a trend of reduction in hospitalizations during the studied period.

Figure 4 presents hospitalization rates per thousand inhabitants for the years 2015, 2018, 2021, and 2023. In 2015, the municipalities with the highest hospitalization rates per thousand inhabitants were Lavras do Sul (18.55), Horizontina (17.63), Novo Hamburgo (13.94), Parobé (13.69), and Bagé (13.67). In 2018, Lavras do Sul remained the municipality with the highest rate, with 10.24 hospitalizations per thousand inhabitants, followed by Mata (8.16), Boqueirão do Leão (6.28), and Aceguá (4.68). In 2021, Boqueirão do Leão and Aceguá continued to have rates above 4, registering 4.42 and 4.29, respectively. In 2023, a slight increase was observed compared to the previous year, with Aceguá leading the hospitalization rates (5.99), followed by Dom Pedrito (5.33), Porto Xavier (4.73), and Alecrim (4.41).

Comparing 2023 with 2015, there was a 32.3% decrease in the hospitalization rate due to malnutrition in the state of Rio Grande do Sul. However, comparing 2023 with 2021, there was an increase of 39.6% in the hospitalization rate. It is important to note that these cited rates do not refer to the same municipalities but provide an overall view comparing the maximum rates.

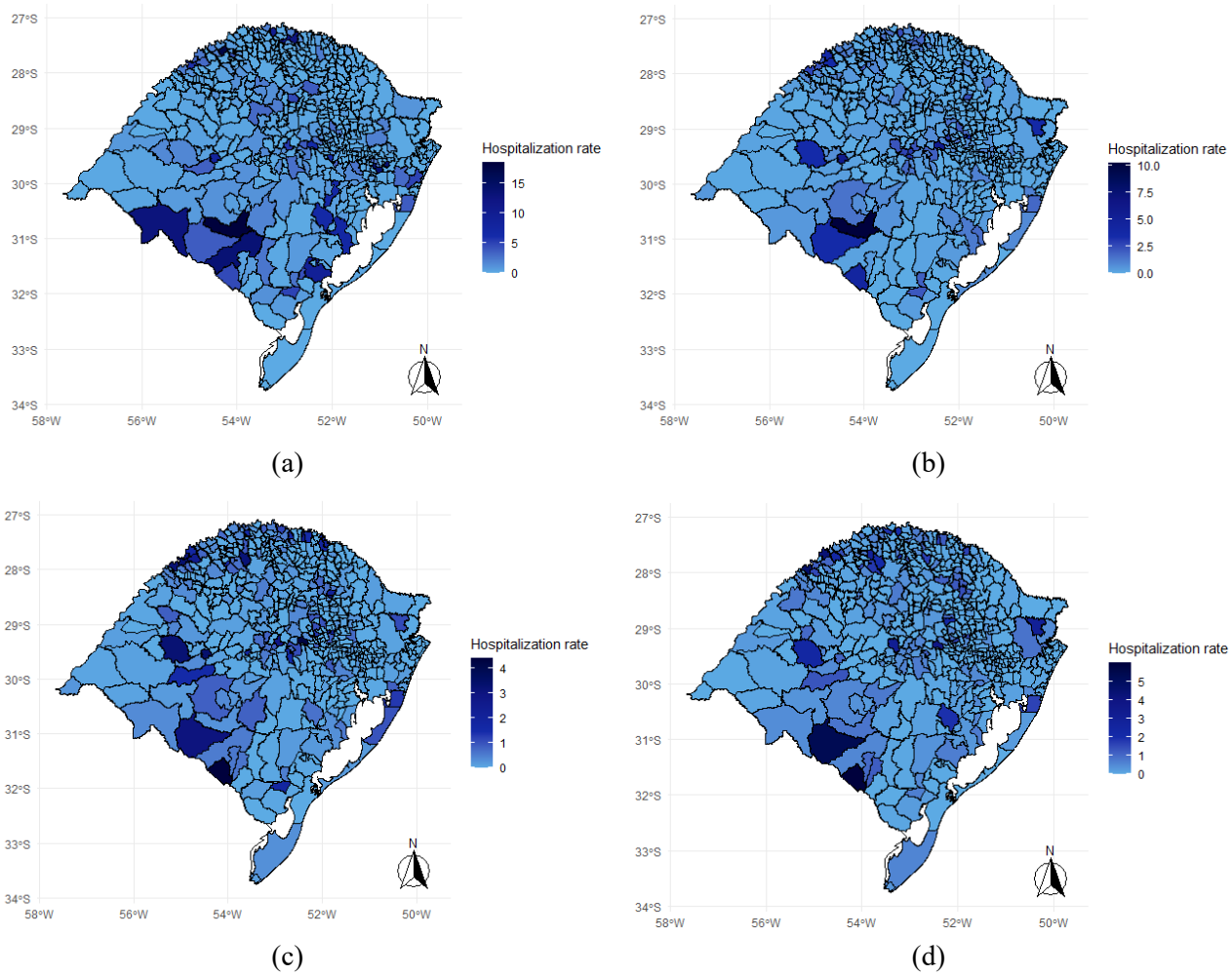


Figure 4. Spatial distribution of hospitalization rates due to malnutrition per thousand inhabitants in the municipalities of RS in the years: a) 2015, b) 2018, c) 2021, and d) 2023.

The global Moran's indices, presented in Table 4, reveal a positive and significant spatial association in all the years analyzed. However, the index values were very low, close to zero, indicating a weak intensity of this spatial association.

Table 4. Spatial autocorrelation test: Moran's index of hospitalization rates due to malnutrition in the municipalities of RS in the years 2015, 2018, 2021, and 2023

Year of hospitalization	Global Moran's Index	p-value
2015	0.11	<0.001
2018	0.17	<0.001
2021	0.17	<0.001
2023	0.11	<0.001

The Moran Scatterplot, presented in Figure 5, generally shows a high concentration of hospitalization rates in quadrants Q1 and Q2, evidencing the presence of positive spatial autocorrelation. This indicates that municipalities tend to have neighbors with similar hospitalization rates. In addition, a significant concentration of hospitalization rates is observed in Q4, indicating the existence of several municipalities with low malnutrition hospitalization rates that are surrounded by neighbors with high hospitalization rates, throughout all the analyzed years.

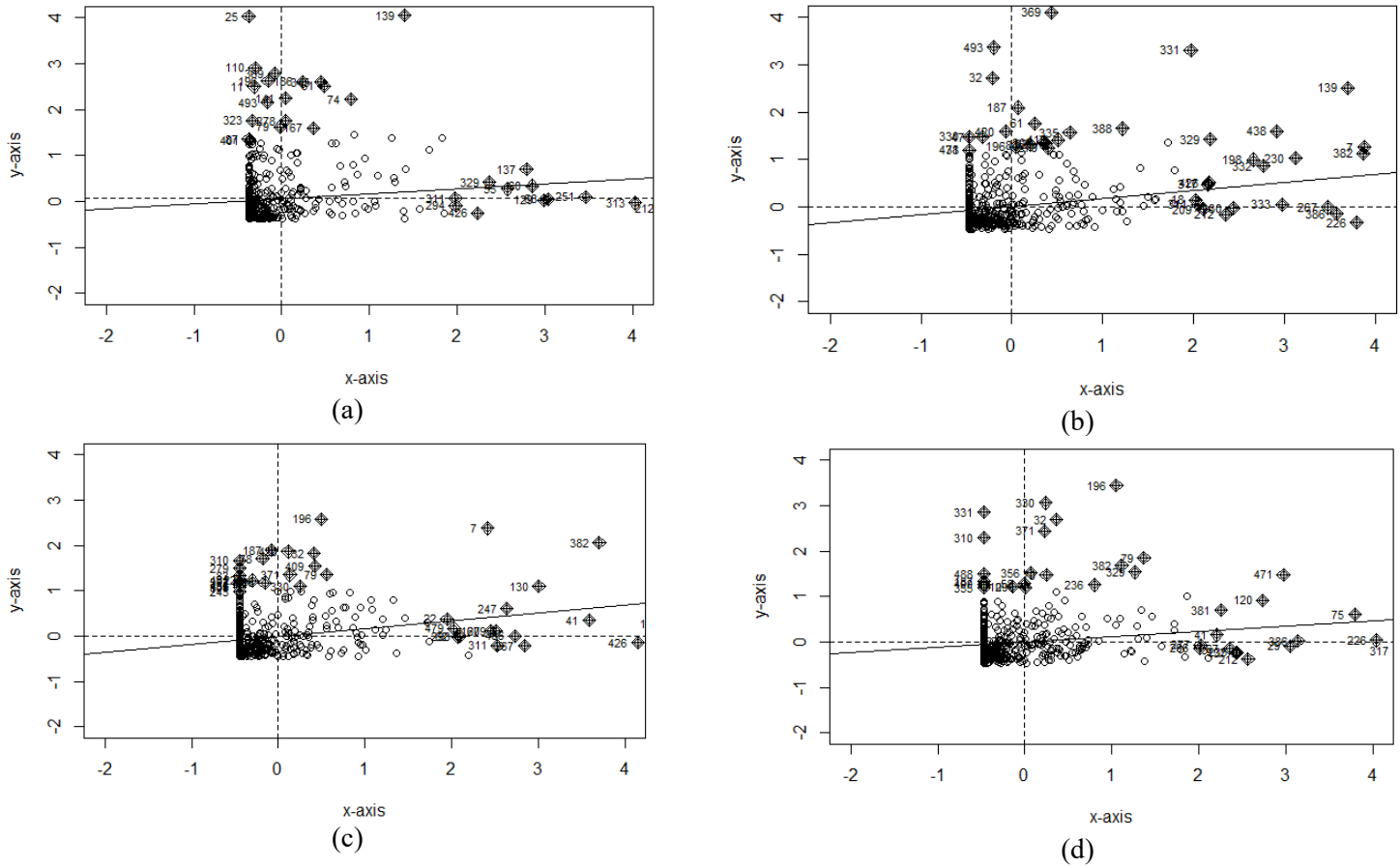


Figure 5. Moran Scatterplot of hospitalization rates due to malnutrition in the municipalities of RS in the years: a) 2015, b) 2018, c) 2021, and d) 2023, where the numbers shown correspond to the municipality IDs.

In the significance map, presented in Figure 6, most municipalities do not exhibit statistically significant spatial autocorrelation; that is, even though municipalities may be geographically close to others with similar (or different) values, this proximity is not strong enough to be considered significant.

Some municipalities in the state do show significant spatial autocorrelation, particularly those located in the Western Border region. For example, Dom Pedrito (code 139) exhibited positive autocorrelation, values similar to its neighbors, only in the first two years of the study. In 2015, the municipality of Bagé (code 31) also showed positive autocorrelation, which became negative the following year, indicating values different from its neighbors, returning to positive in 2021 and 2023. Santana do Livramento (code 371), on the other hand, did not show autocorrelation in 2015 but demonstrated positive autocorrelation in subsequent years.

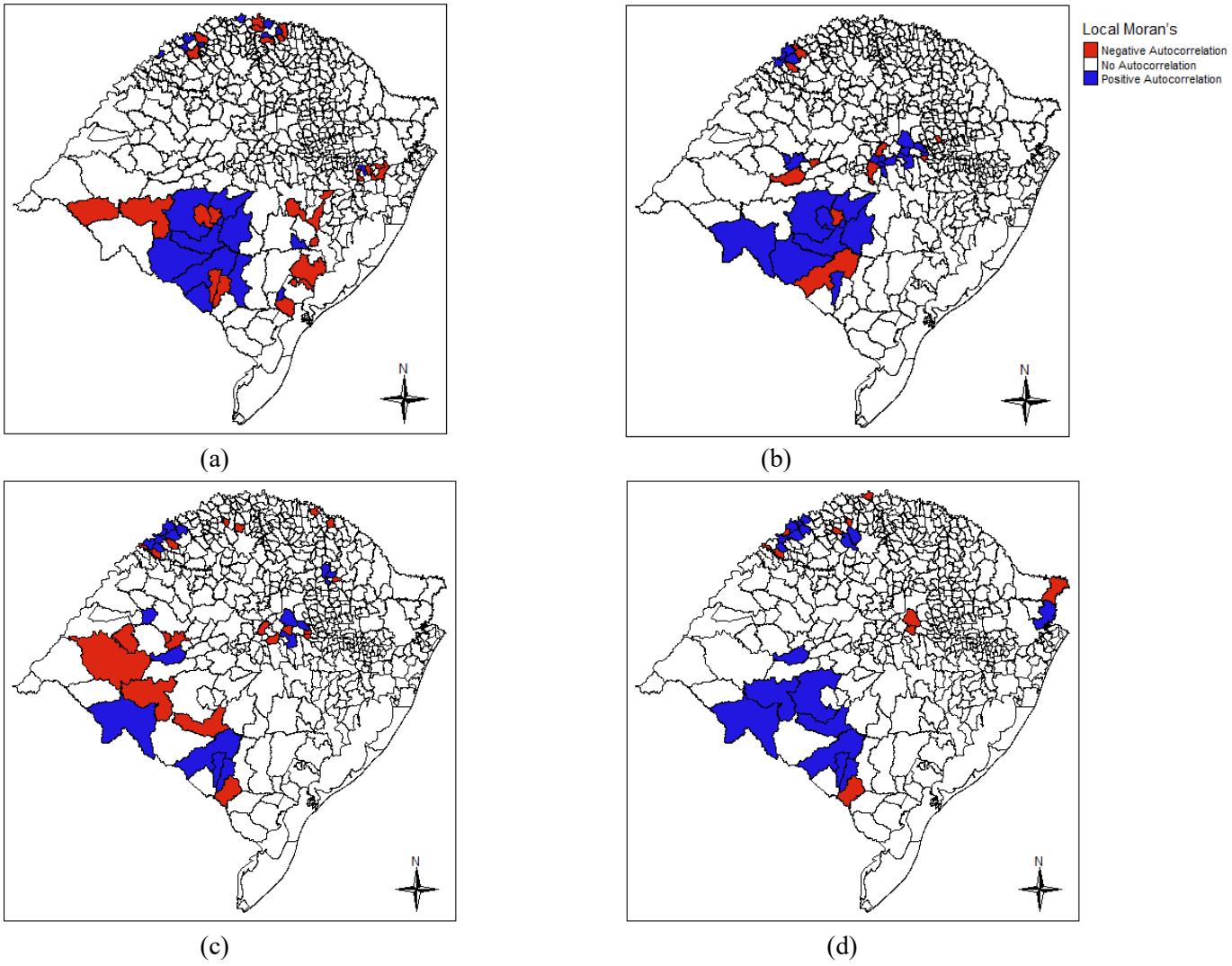


Figure 6. Significance map for the local Moran's indices of hospitalization rates due to malnutrition in the municipalities of RS in the years: a) 2015, b) 2018, c) 2021, and d) 2023.

In the cluster map (Figure 7), spatial autocorrelation is observed in most municipalities. However, some significant clusters can be identified, again highlighting municipalities in the Campanha and Western Border regions. These regions exhibit two types of clusters: high-high (municipality with a high hospitalization rate surrounded by neighbors with high rates) and low-high (municipality with a low hospitalization rate surrounded by neighbors with high rates).

Some municipalities showed notable patterns in the analyzed clusters. São Gabriel (code 388) was in the high-high cluster in 2015, 2018, and 2023, but was considered non-significant in 2021. Lavras do Sul (code 236) stood out for remaining in the high-high cluster in all years except 2021, when it was low-high. Bagé (code 32) had a similar pattern, appearing as low-high only in 2018, while in the other years it was high-high. Porto Vera Cruz (code 331) exhibited high rates in the first three years (high-high), but in 2023 it had a low rate with high-rate neighbors. Hulha Negra (code 196) was low-high in 2015 and high-high in the following years. Santana do Livramento (code 371) was not significant in 2015 but maintained the high-high pattern in the other years.

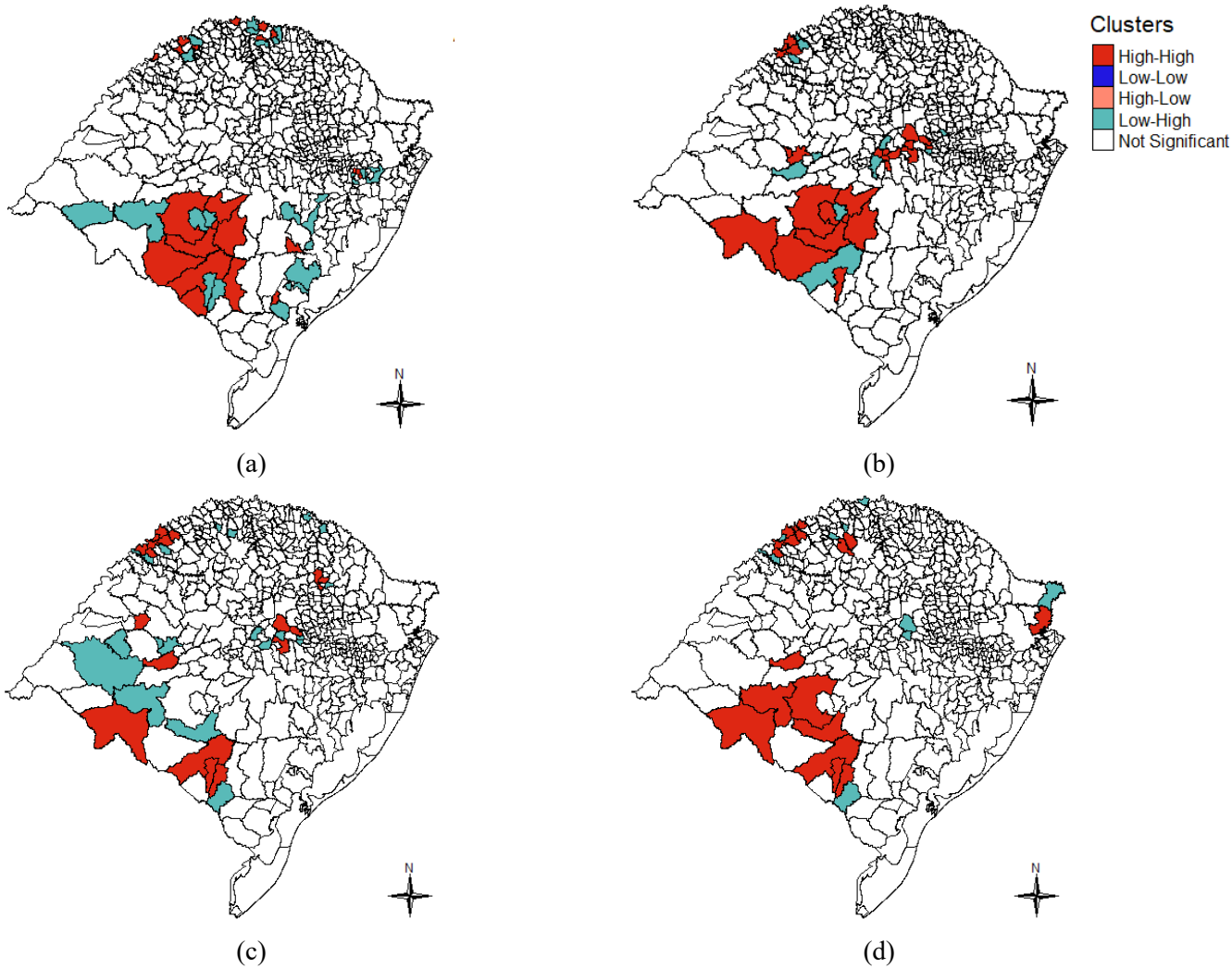


Figure 7. Cluster map for the local Moran's indices of hospitalization rates due to malnutrition in the municipalities of RS in the years: a) 2015, b) 2018, c) 2021, and d) 2023.

4. Discussion

The results show that the older adults group had a significant predominance in hospital admissions, as highlighted in studies by Faria & Costa (2022), Portela & Cebola (2021), and Dent *et al.* (2023). These authors emphasize the vulnerability of this age group, noting that aging is associated with a higher prevalence of comorbidities, frailty, and complications that often require hospitalization. The studies also underscore the importance of specific care and comprehensive attention tailored to the needs of older adults, including prevention strategies, continuous monitoring, and interventions aimed at promoting health and quality of life.

Although older adults represent the majority of cases, there is still a lack of specific public policies targeting malnutrition in this age group. The National Policy for Older Adults, despite its broad scope, primarily focuses on ensuring the social rights of this population, promoting autonomy, integration, and active participation in society. However, there is a gap in directly addressing issues such as malnutrition, which requires more targeted strategies to meet the nutritional and health needs of this vulnerable segment of the population.

In the study conducted by Da Paixão *et al.* (2020) on malnutrition-related mortality among older adults, similar results were found regarding gender in the state of Mato Grosso do Sul, where 56.12% of deaths occurred among men. In 2009, the National Policy for Comprehensive Men's Health Care

(PNAISH) was created to improve the health conditions of the Brazilian male population and effectively contribute to reducing morbidity and mortality in this group. According to the analysis by Alves *et al.* (2020), 70.3% of respondents reported not knowing about PNAISH. Furthermore, the study revealed that men evaluated first-contact access negatively, perceiving it as poorly suited to primary health care.

Moreover, hospitalizations due to malnutrition in Rio Grande do Sul have shown variation over time. The progressive decrease in hospitalizations over the years occurred in much of the state; however, it was not homogeneous, with higher rates observed in poorer and more vulnerable regions. This decrease may be associated with the implementation and strengthening of public policies aimed at combating malnutrition and poverty. As highlighted by Souza & Heller (2021), initiatives such as the Bolsa Família Program and the expansion of access to basic sanitation play a key role in reducing cases of malnutrition, contributing to improvements in child health indicators.

According to malnutrition data provided by the Ministry of Health, several strategies have been developed to prevent and control malnutrition. Among the measures adopted, the promotion of exclusive breastfeeding until six months of age and the introduction of healthy complementary feeding, while maintaining breastfeeding until two years of age, stand out, as recommended by the *Amamenta e Alimenta Brasil* Strategy. In addition, measures focusing on the supplementation of critical nutrients, such as iron, folic acid, and vitamin A, are primarily directed toward groups at higher vulnerability.

In 2023, there was an increase in hospitalization rates in Rio Grande do Sul, following a global trend. According to FAO (2024), around 733 million people faced hunger in 2023, which corresponds to approximately one in every eleven people worldwide. This scenario highlights the worsening of hunger, especially in Africa, while also revealing concerning developments in Latin America. The FAO (2024) report further points out that the double burden of malnutrition, defined as the coexistence of undernutrition along with overweight and obesity, has increased globally across all age groups. Thinness and underweight have decreased over the past two decades, whereas obesity has risen sharply.

Nutritional monitoring of children under five years of age, carried out by the Food and Nutrition Surveillance System (SISVAN), provides an important tool for follow-up and intervention, with particular focus on families benefiting from the *Bolsa Família* Program. These actions demonstrate a continuous commitment to improving child health and nutrition conditions, as well as strengthening public policies in this area, with the goal of promoting healthy development from the earliest years of life. In this way, these measures contribute significantly to reducing malnutrition rates among children.

Despite these efforts, challenges remain, as revealed by hospitalization patterns due to malnutrition in Rio Grande do Sul. The results of spatial analysis suggest that, although there is a tendency toward spatial clustering, it is not sufficiently strong to be considered statistically significant within the analyzed period. This pattern may indicate that the factors influencing hospitalizations due to malnutrition are more closely related to local or individual characteristics rather than following a well-defined spatial pattern among the municipalities of Rio Grande do Sul.

The results of the local spatial autocorrelation of hospitalizations indicated similar patterns in municipalities of the *Campanha* and *Fronteira Oeste* regions, with high rates surrounded by neighbors also with high rates (high-high), and municipalities with low rates surrounded by neighboring municipalities with high rates (low-high). Figueiredo, Ribeiro & Santos (2020) found similar high-high results when assessing the distribution of hospitalizations due to vascular diseases in the states of Santa Catarina, São Paulo, Mato Grosso do Sul, and in the Federal District during the period 2013–2016. Marques (2020) also evidenced the formation of high-high clusters in municipalities of the North, Northeast, Southeast, and Midwest regions when considering the spatial distribution of diabetes mortality in Brazil.

The results become more evident when examined in light of the socioeconomic and infrastructural conditions of the municipalities analyzed. In 2020, only 33.5% of the population of Rio Grande do Sul had access to sanitary sewage services a concerning figure given its direct implications for public health. In the Campanha and Fronteira Oeste region, the indicators also reveal pronounced inequalities: in 2010, Lavras do Sul and Aceguá reported Municipal Human Development Index (MHDI) values of

0.699 and 0.687, respectively, both below the state average. Economically, Santana do Livramento and Bagé exhibited GDP per capita levels below the state average (R$ 37,330.14 and R$ 30,846.53), although Bagé showed a relatively higher MHDI (0.740). Dom Pedrito also presented values below the statewide level, with an MHDI of 0.708 and a GDP per capita of R$ 57,844.71. These indicators underscore how structural inequalities shape nutritional vulnerability and the hospitalization patterns identified in this study.

Finally, studying the distribution of wasting and malnutrition in children living in Piauí from 2007 to 2022, Alves (2023) observed high-high and low-high distribution patterns in municipalities in the central part of the state. However, in municipalities in the northern and western portions, low-low autocorrelations were identified (and, to a lesser extent, high-low autocorrelations).

5. Conclusions

The study identified a concerning predominance of malnutrition-related hospitalizations among older adults, who represented 67.3% of all cases included in the analysis. This finding highlights the high vulnerability of this age group and reinforces the need for prioritization by public authorities. This scenario underscores the urgency of developing and implementing specific public policies to address the demands of this population, as well as reinforcing the importance of research aimed at better understanding the health conditions of the older adults.

Furthermore, hospitalizations attributable to malnutrition declined by 32.3% between 2015 and 2023. However, it was possible to identify a pattern in certain regions of the state that consistently exhibited the highest hospitalization rates related to this condition. These findings indicate persistent regional inequalities and suggest the need for more targeted interventions in these areas, with the aim of reducing disparities and improving the nutritional health of the population.

The spatial analysis among municipalities during the study periods demonstrated a globally weak but positive spatial autocorrelation. Higher rates of hospitalizations for malnutrition were also identified in the southwest/western regions, with clusters of high-high and low-high autocorrelations. Special attention should be directed to municipalities showing a high-high autocorrelation trend, such as São Gabriel, Lavras do Sul, Bagé, Hulha Negra, and Santana do Livramento, since these areas presented concerning patterns of hospitalizations throughout the years.

For future research, it is suggested to conduct in-depth analyses of socioeconomic factors in order to identify potential determinants influencing the prevalence of malnutrition. This approach could involve evaluating the impact of variables such as income level, educational attainment, access to healthcare services, housing conditions, and the HDI at the municipal level. Understanding these relationships would allow for the development of more effective and targeted strategies for the prevention of malnutrition, especially in regions with greater socioeconomic vulnerability.

Building on these recommendations, this study provides practical contributions to territorial planning and regional health policies by offering evidence to support resource allocation and prioritize municipalities with the greatest vulnerability. Identifying spatial and temporal patterns of malnutrition-related hospitalizations strengthens the development of targeted interventions that account for local disparities. Moreover, the methodological framework employed, integrating spatial analysis with municipal-level indicators, constitutes a reproducible model that can be applied in other states or comparable settings. Replicating this approach may enhance cross-regional comparisons and contribute to more effective and equitable public health strategies.

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Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: LEONARDI, I. S.; JACOBI, L.F.; MATEUS, A. L. S. S. **Data curation:** LEONARDI, I. S; JACOBI, L.F. **Formal analysis:** LEONARDI, I. S.; JACOBI, L.F.; MATEUS, A. L. S. S. **Funding acquisition: Investigation:** LEONARDI, I. S.; JACOBI, L.F.; MATEUS, A. L. S. S. **Methodology:** LEONARDI, I. S.; JACOBI, L.F.; MATEUS, A. L. S. S. **Project administration:** LEONARDI, I. S.; JACOBI, L.F.; MATEUS, A. L. S. S. **Software:** LEONARDI, I. S. **Resources: Supervision:** LEONARDI, I. S.; JACOBI, L.F.; MATEUS, A. L. S. S. **Validation:** LEONARDI, I. S.; JACOBI, L.F.; MATEUS, A. L. S. S.; SOUZA A. M. **Visualization: Writing - original draft:** LEONARDI, I. S. **Writing - review and editing:** LEONARDI, I. S.; JACOBI, L.F.; MATEUS, A. L. S. S.; SOUZA A. M.

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