

Chagas Disease mortality in Northeastern Brazil: Trends and spatial analysis (2012–2023)

Mortalidade por Doença de Chagas no Nordeste do Brasil: Tendências e análise espacial (2012–2023)

Mortalidad por Enfermedad de Chagas en el Nordeste de Brasil: Tendencias y análisis espacial (2012–2023)

Received: 06/16/2025 | Revised: 06/20/2025 | Accepted: 06/20/2025 | Published: 06/23/2025

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Abstract

Aim: To investigate the spatial patterns and temporal trends of Chagas disease (CD)-related mortality in northeastern Brazil and to evaluate its association with socioeconomic and demographic risk factors. **Methods:** This ecological study used data from the Brazilian Mortality Information System (2012–2023). Temporal trends were analyzed using Joinpoint software, and spatial distribution was assessed via Moran's I statistic. The rationale for focusing on northeastern Brazil stems from its historically high endemicity, socioeconomic vulnerabilities, and persistent health inequities, making it a priority area for epidemiological surveillance and health planning. **Results:** A total of 11,934 CD-related deaths were recorded, predominantly in males (58.2%), individuals over 50 years (88.4%), those of brown ethnicity (59.4%), and with low schooling (63%). Overall, mortality rates declined (AAPC = -1.54; 95% CI: -2.1 to -1.1), though trends varied across states. No global spatial autocorrelation was detected (Moran's I = 0.4; $p = 0.35$), but local analysis (LISA) identified Bahia, Alagoas, and Pernambuco as hotspots. **Conclusion:** CD-related mortality in northeastern Brazil shows a modest declining trend but persists with significant regional disparities linked to socioeconomic factors. This study highlights the urgent need for region-specific public health strategies and targeted interventions.

Keywords: Chagas disease; Mortality; Temporal trends; Spatial analysis.

Resumo

Objetivo: Investigar os padrões espaciais e as tendências temporais da mortalidade relacionada à doença de Chagas (DC) no Nordeste do Brasil e avaliar sua associação com fatores de risco socioeconômicos e demográficos. **Métodos:** Este estudo ecológico utilizou dados do Sistema de Informações sobre Mortalidade (SIM) do Brasil (2012–2023). As tendências temporais foram analisadas por meio do software Joinpoint, e a distribuição espacial foi avaliada utilizando o índice de Moran. O foco no Nordeste do Brasil se justifica por sua histórica alta endemicidade, vulnerabilidades socioeconômicas e persistentes desigualdades em saúde, tornando a região uma prioridade para vigilância epidemiológica e planejamento em saúde. **Resultados:** Foram registrados 11.934 óbitos relacionados à DC, predominantemente em homens (58,2%), indivíduos com mais de 50 anos (88,4%), pardos (59,4%) e com baixa escolaridade (63%). Houve redução geral das taxas de mortalidade (AAPC = -1,54; IC95%: -2,1 a -1,1), embora as tendências tenham variado entre os estados. Não foi detectada autocorrelação espacial global (índice de Moran = 0,4; $p = 0,35$), mas a análise local (LISA) identificou Bahia, Alagoas e Pernambuco como áreas de maior risco. **Conclusão:** A mortalidade por DC no Nordeste do Brasil apresenta uma tendência de declínio modesta, mas persiste com disparidades regionais significativas associadas a fatores socioeconômicos. Este estudo destaca a necessidade urgente de estratégias de saúde pública regionais e intervenções específicas.

Palavras-chave: Doença de Chagas; Mortalidade; Tendências temporais; Análise espacial.

Resumen

Objetivo: Investigar los patrones espaciales y las tendencias temporales de la mortalidad relacionada con la enfermedad de Chagas (EC) en el nordeste de Brasil y evaluar su asociación con factores de riesgo socioeconómicos y

demográficos. Métodos: Este estudio ecológico utilizó datos del Sistema de Información de Mortalidad de Brasil (SIM) (2012-2023). Las tendencias temporales se analizaron utilizando el software Joinpoint, y la distribución espacial se evaluó utilizando el índice de Moran. El enfoque en el Nordeste de Brasil se justifica por su alta endemidad histórica, las vulnerabilidades socioeconómicas y las persistentes desigualdades en salud, lo que convierte a la región en una prioridad para la vigilancia epidemiológica y la planificación sanitaria. Resultados: Se registraron 11.934 muertes relacionadas con la EC, predominantemente en hombres (58,2%), individuos mayores de 50 años (88,4%), morenos (59,4%) y con baja escolaridad (63%). Hubo una reducción global de las tasas de mortalidad (AAPC = -1,54; IC 95%: -2,1 a -1,1), aunque las tendencias variaron entre estados. No se detectó autocorrelación espacial global (índice de Moran = 0,4; $p = 0,35$), pero el análisis local (LISA) identificó Bahía, Alagoas y Pernambuco como zonas de mayor riesgo. Conclusión: La mortalidad por EC en el Nordeste de Brasil muestra una modesta tendencia a la baja, pero persiste con importantes disparidades regionales asociadas a factores socioeconómicos. Este estudio subraya la necesidad urgente de estrategias regionales de salud pública e intervenciones específicas.

Palabras clave: Enfermedad de Chagas; Mortalidad; Tendencias temporales; Análisis espacial.

1. Introduction

Chagas disease (CD) is a neglected disease caused by the hemoflagellate protozoan *Trypanosoma cruzi*¹ and can be transmitted via vectorial, oral, transfusion, congenital, organ transplant and laboratory accidents (Chagas, 1909; Coura & Castro, 2003; Dias et al., 2016; PAHO, 2020; WHO, 2020).⁵ This disease affects millions of people worldwide and remains an important public health problem and an expressive morbidity and mortality, especially among adults and older adults.^{1,2} It is and endemic zoonosis in 21 countries in the Americas, including Brazil (WHO, 2020; Cucunubá et al., 2024).

Despite the decrease in the incidence of Chagas disease in Brazil, the infections that occurred in the past still have a great impact on health services in the country (Peres et al., 2022).⁷ This is a debilitating disease that can impact the quality of life of patients and can lead to death (Dias et al., 2016; Peres et al., 2022).

The CD can be characterized in two phases, acute and chronic phases (Andrade et al., 2011; Rassi & Marin-Neto, 2010). The chronic phase receives more attention for presenting different clinical forms, namely: indeterminate, cardiac, and digestive forms (Rassi & Marin-Neto, 2010; Andrade et al., 2011; Dias et al., 2016). Among these clinical forms, the indeterminate form is the most prevalent; however, the cardiac form is responsible for the greatest morbidity and mortality of the disease (Dias et al., 2016).

Estimates indicate that in Brazil there are about 1 million infected people (SVS, 2021), however this number is questionable, since the study by Martins-Melo et al., (2014), showed that there are approximately 4.6 million infected Brazilians and, according to the Brazilian Department of Health Informatics (DATASUS), 94,788 deaths from CD were recorded in the country from 2000 to 2019 (DATASUS, 2021).

This study specifically focused on northeastern Brazil, rather than the entire country, due to the region's high burden of CD-related morbidity and mortality, historical endemicity, and pronounced social inequalities. Northeastern Brazil comprises nine states (Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Sergipe), each with unique demographic, geographic, and healthcare access profiles. The decision to restrict the analysis to these states was driven by the need for targeted regional insights that can inform local public health policy and intervention design.

Given the chronic nature of Chagas disease and its importance to public health in Brazil, studies such as this one that evaluate mortality trends can contribute to the development of health policies, planning of health services and evaluation of the impact of the disease on the population (Nolte & McKee, 2004), providing complete and accurate data, particularly on the causes of mortality that guide high quality public health decision making (Oliveira et al., 2021). Therefore, the aim of this study was to present an analysis of CD mortality in the Northeast of Brazil, also considering the spatial patterns and the temporal trend of deaths from 2012 to 2023.

2. Methodology

Study type – It is an ecological, descriptive, and analytical study of qualitative and quantitative nature (Pereira et al., 2018) based on secondary data of Chagas disease mortality in Northeast Brazil, from 2012 to 2023 and, in this study we used simple descriptive statistics with data classes, absolute frequencies in quantity and relative frequencies in percentages (Shitsuka et al., 2015; Akamine & Yamamoto, 2009).

Population and data collection - We assessed the CD mortality in the northeast region of Brazil (Alagoas [AL], Bahia [BA], Ceará [CE], Maranhão [MA], Paraíba [PB], Pernambuco [PE], Piauí [PI], Rio Grande do Norte [RN], and Sergipe [SE]), from 2012 to 2021. Data were retrieved from the Brazilian Mortality Information System (SIM), Health Informatics Department (DATASUS), Brazil Ministry of Health. The variables analyzed were age, sex, race/color, schooling, place of birth, municipality of residence, and notified deaths from CD. The reference codes for disease classification were based on the International Classification of Diseases (ICD) version 10 (WHO, 2007). The ICD for Chagas disease is B57. The subcategories for CD were: B570 (Acute with heart involvement); B571 (Acute without heart involvement); B572 (Chronic with heart involvement); B573 (Chronic with digestive system involvement); B574 (Chronic with nervous system involvement), and B575 (Chronic with the involvement of other organs). The annual population projections for the Federal Court of Audit were harvested from DataSUS (available at <https://datasus.saude.gov.br/populacao-residente>) for mortalities index calculation.

Data Analysis - Statistical analyses were performed using Jamovi project version 2.3.28 for the Windows program. Quantitative data were presented as mean and standard deviation (sd). Qualitative data were presented by their absolute and relative frequencies. The mortality rate (with 95% confidence interval – CI) for CD in each state in the period indicated was calculated using the average numbered deaths and the average population from 2012 to 2023 as the denominator and multiplied per 100,000 inhabitants. Based on mortality, the relative risks (RR) and 95% CI of each group were calculated.

Time trend analysis was performed using the Joinpoint linear regression analysis to assess changes in the trend in the mortality of CD over the years, considering as dependent variable the number of CD deaths and as independent variable the year in which the cases were recorded (2012-2023). The temporal trend was considered decreasing if both values of the 95% confidence interval (CI95) were negative; increasing, if these values were positive; and stationary when the confidence interval crosses the zero value, i.e., the lower and upper limits have opposite signs (Campoy et al., 2020).

The annual mortality average was used to build thematic Maps were created using QGIS v. 3.22.4 using publicly available shapefiles (available at www.ibge.gov.br). TerraView v. 5.3.6 software was used to analyze and calculate spatial autocorrelation indicators. The spatial dependence of the mortality of CD was tested using the global Moran's index, which ranges from -1 (negative autocorrelation) to +1 (positive autocorrelation), where 0 (zero) indicates the absence of spatial autocorrelation; local Moran's index, which results in the Local Indicators of Spatial Association (LISA) that assigns a value of statistical significance ($P < 0.05$) for each state (polygon). Moran's dispersion diagram was used to verify patterns of local association among states and their neighbors (Q1 – states with a high prevalence surrounded by states that also have a high average prevalence (High – High); Q2 - states with low prevalence surrounded by states also with low average prevalence (Low – Low); Q3 – states with high prevalence surrounded by states with low prevalence (High – Low); and Q4 – states with low prevalence surrounded by states with high prevalence (Low – High). The high-high and low-low categories represent areas of clusters and the high-low and low-high categories indicate epidemiological transition areas. Moran and LISA maps were created to graphically visualize the spatial dependence of the data, considering the statistical significance and the association pattern. Local Empirical Bayes Smoothing (LEBS) was used to reduce random variability and provide greater stability in mortality rates. LEBS was applied to stabilize mortality rates across municipalities by reducing random variability, particularly

in areas with small populations or low event counts. This method combines observed local rates with the global or regional mean, weighting the adjustment according to population size and variability, resulting in more stable and reliable estimates of spatial patterns. The smoothing process was performed using TerraView (version 5.3.6), which implements an empirical Bayesian hierarchical model to adjust crude rates. This approach is especially useful in spatial analysis, as it enhances the visualization and interpretation of patterns by minimizing the influence of random fluctuations (Martins-Melo et al., 2015).

Ethical aspects - As this is an analysis based on a secondary database in the public domain, the study was not referred to a Research Ethics Committee. Still, it should be emphasized that the ethical precautions set forth in Resolution 466/12 of the National Health Council were taken.

3. Results

A total of 4,318,309 deaths were recorded in Northeastern Brazil between 2012 and 2023, of which 11,934 (0.3%) were attributed to Chagas disease (CD) (Table 1). Most deaths occurred in males (58.2%), with a mean age of 67.5 ± 14.5 years (ranging from 8 to 117 years). The most prevalent age group was ≥ 50 years (88.4%). The most frequent race/ethnicity was Brown (59.4%), and the predominant educational level was low, with illiterate individuals and those with incomplete elementary schooling being the majority (Table 1). Mortality rates were higher among males (RR = 1.31; 95% CI: 1.16–1.5), individuals identified as Black (RR = 2.96; 95% CI: 2.39–3.67), and illiterate individuals (Table 1).

Table 1 – Epidemiological data and features to Chagas disease age-adjusted mortality per 100,000 inhabitants in the northeast of Brazil (2012 – 2023).

Variables	Total of deaths (%)	Standardized Mortality per 100,000 inhabitants (95% CI)	Relative Risk (95% CI)
All deaths by Chagas disease	11,934 (100%)	1.78 (1.71 – 1.82)	
Sex*			
Male	6,947 (58.2%)	1.34 (1.89 – 2.09)	1.31 (1.16 -1.5)
Female	4,986 (41.8%)	1.51 (1.47 – 1.57)	0.76 (0.67 – 0.86)
Age (years)			
5 - 19	14 (0.12%)	0.009 (0.00 – 0.02)	1
20 - 49	1,366 (11.4%)	0.439 (0.36 – 0.52)	60.9 (8.5 – 435.9)
≥ 50	10,554 (88.4%)	7.196 (6.75 – 7.20)	996.3 (140.2 – 7080)
Race*			
White	1,807 (15.1%)	1.070 (1.02 – 1.12)	1
Brown	7,092 (59.4%)	2.911 (0.14 - 5.69)	1.66 (1.39 - 1.99)
Black	2,229 (18.7%)	3.229 (2.89 – 3.56)	2.96 (2.39 - 3.67)
Yellow	33 (0.3%)	-	-
Indigenous	26 (0.2%)	-	-
Schooling*[#]			
Illiterate	3,685 (30.9%)	5.540 (4.95 – 6.13)	1
Elementary School	3,825 (32.1%)	1.678 (1.53 – 1.82)	0.03 (0.29 – 0.32)
Middle School	1,111 (9.3%)	1.723 (1.35 – 2.10)	0.31 (0.25 – 0.40)
High School	555 (4.7%)	0.303 (0.27 – 0.33)	0.06 (0.04 – 0.08)
Incomplete Higher Education	34 (0.3%)	0.089 (-0.01 – 0.19)	0.02 (0 - 0.06)
Complete Higher Education	62 (0.5%)	0.108 (-0.01 – 0.23)	0.02 (0.01 – 0.05)

*Data not informed or ignored: sex (1 case); race (747/6.3% case) and Schooling (2662/22.3% cases). [#]Indices calculated only for the 2016-2019 population bases. CI 95% - Confidence interval 95%. Source: Research data (2025).

Regarding clinical forms, the chronic cardiac form was the leading cause of death, accounting for 77.5% of cases, followed by the chronic digestive form (12.6%) (Table 2). The state of Bahia reported the highest number of deaths for all clinical forms, followed by Pernambuco (Table 2). The highest absolute number of deaths occurred in 2012 (1,070), with Bahia (7,225), Pernambuco (1,410), and Alagoas (1,042) recording the largest numbers (Table 2).

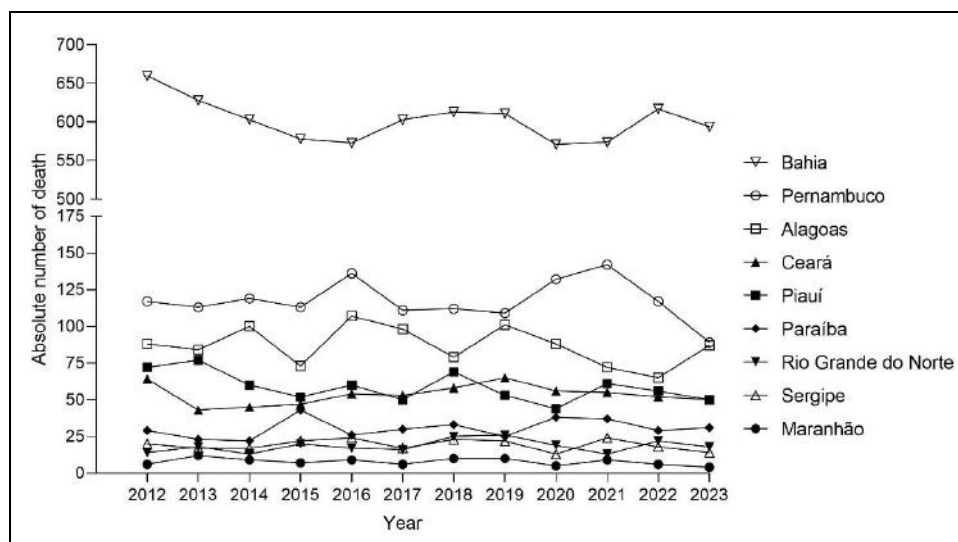
Table 2 – Distribution of Chagas disease deaths according to clinical classification (2012 – 2023).

States	CID B570	CID B571	CID B572	CID B573	CID B574	CID B575
Maranhão	9 (1.3%)	2 (1.2%)	64 (0.7%)	10 (0.7%)	4 (4.3%)	4 (1.7%)
Piauí	45 (6.7%)	9 (5.5%)	519 (5.6%)	104 (6.9%)	11 (9.5%)	16 (6.8%)
Ceará	36 (5.3%)	9 (5.5%)	488 (5.3%)	71 (4.7%)	11 (9.5%)	27 (11.4%)
Rio Grande do Norte	19 (2.8%)	6 (3.7%)	180 (1.9%)	10 (0.7%)	1 (0.9%)	5 (2.1%)
Paraíba	60 (8.9%)	7 (4.3%)	246 (2.7%)	28 (1.9%)	5 (4.3%)	20 (8.4%)
Pernambuco	69 (10.3%)	33 (20.2%)	1076 (11.6%)	180 (12.0%)	10 (8.6%)	42 (17.7%)
Alagoas	20 (3.0%)	6 (3.7%)	886 (9.6%)	92 (6.1%)	7 (6.0%)	31 (13.1%)
Sergipe	11 (1.6%)	6 (3.7%)	169 (1.8%)	40 (2.7%)	5 (4.3%)	0 (0%)
Bahia	404 (60.0%)	85 (52.1%)	5617 (60.8%)	965 (64.3%)	62 (53.4%)	92 (38.8%)
Nordeste	673 (5.6%)	163 (1.4%)	9,245 (77.5%)	1,500 (12.6%)	116 (1.0%)	237 (2.0%)

Legend: Chagas disease classification: B570 – Acute with heart involvement; B571 – Acute without heart involvement; B572 – Chronic with heart involvement; B573 – Chronic with digestive system involvement; B574 – Chronic with nervous system involvement; B575 – Chronic with the involvement of other organs. Source: Research data (2025).

The mean mortality rate was highest in Bahia (4.1/100,000 inhabitants), followed by Alagoas (2.6/100,000 inhabitants) and Piauí (1.8/100,000 inhabitants), with similar patterns observed in empirical Bayes smoothed rates (Figure 1A and B).

Figure 1 - Evolution of the number of deaths from Chagas disease in the northeastern Brazilian states from 2012 to 2023.



Source: Research data (2025).

Time trend analysis showed a significant decline in mortality rates among men from 2.32/100,000 in 2012 to 1.73/100,000 in 2023, with an annual percent change (APC) of -2.6 (95% CI: -3.0 – -2.2). Among women, no statistically significant variation was observed. The age groups 20–49 years and ≥50 years showed significant decreases in mortality rates (Table 3).

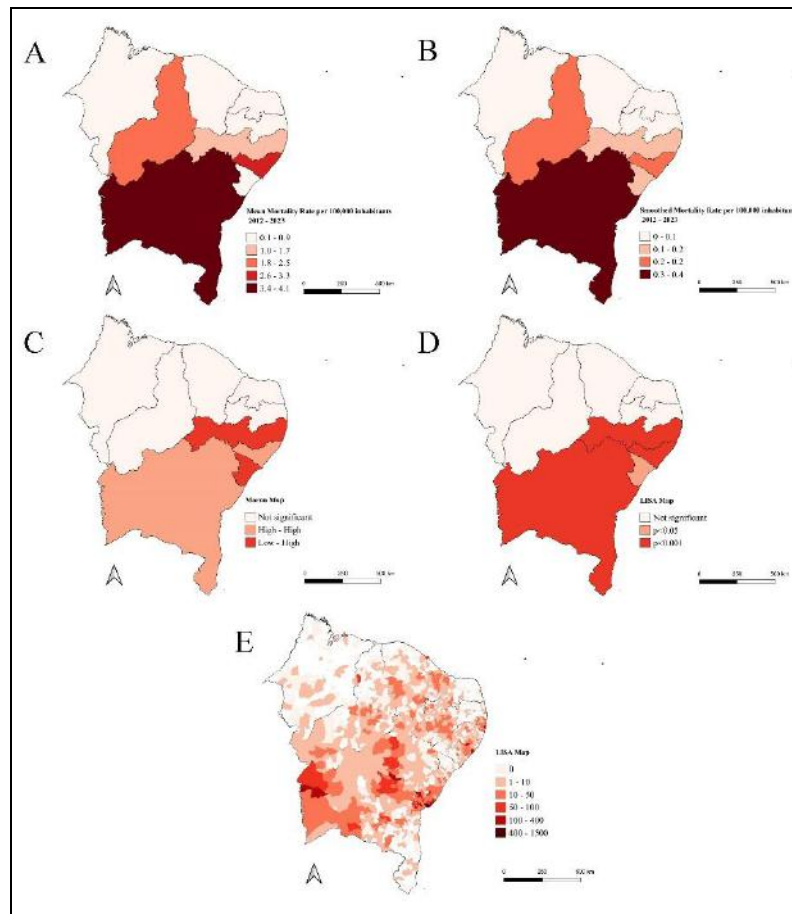
Table 3 – Epidemiological aspects mortality rates per 100,000 inhabitants, related to Chagas disease, and annual percentage change in northeast of Brazil (2012 – 2023).

Epidemiological aspects	Mortality rates (per 100,000)		APC	95% CI
	2012	2023		
Sex				
Female	1.56	1.48	-0.01	-0.9 – 0.9
Male	2.32	1.73	-2.6	-3.0 – -2.2
Age				
5 - 19	0.007	0.000	NC	NC
20 - 49	0.658	0.296	-7.11	-9.3 – - 5.1
≥50	8.610	6.015	-3.1	-3.7 – - 2.4
States				
Maranhão	0.09	0.06	-3.9	-13.7 – 6.4
Piauí	2.24	1.51	-3.1	-7.2 – 0.9
Ceará	0.73	0.54	-2.4	-4.1 – -0.7
Rio Grande do Norte	0.42	0.50	-4.6	-10.8 – 3.3
Paraíba	0.75	0.76	1.2	-3.7 – 6.6
Pernambuco	1.28	0.91	-2.1	-6.0 – 3.2
Alagoas	2.72	2.57	-17.2	-22.7 – -0.6
Sergipe	0.93	0.59	-1.4	-7.0 – 4.6
Bahia	4.60	3.94	-1.2	-2.3 – 0.7
Northeast	1.95	1.61	-1.54	-2.1 – -.0

Legend: APC - Annual percentage change; CI 95% - Confidence interval 95%; NC – Not calculated. Source: Research data (2025).

Regionally, the overall trend revealed a decline in CD mortality in the Northeast, with APC = -1.54 (95% CI: -2.1 – -1.0). Six out of nine states showed non-significant decreasing trends (Bahia, Maranhão, Piauí, Rio Grande do Norte, Pernambuco, and Sergipe); two states exhibited significant declining trends (Alagoas and Ceará), and one state (Paraíba) showed a slight, non-significant increase (Table 2 and Figure 2).

Figure 2 - Geographical distribution and spatial analysis of the Chagas disease mortality rate in northeastern Brazil between 2012 and 2023.



Legend: (A) Mean mortality rate between 2012 - 2013; (B) smoothed rates by the local empirical Bayesian between 2012 - 2023; (C) Moran map; (D) LISA map; (E) geographical distribution of absolute number of deaths. Source: Research data (2025).

The regional trend showed three periods: a significant decrease from 2012 to 2015 ($APC = -3.8$; 95% CI: $-7.4 - -1.5$); a non-significant increase from 2015 to 2018 ($APC = 1.5$; 95% CI: $-0.4 - 3.4$); and a significant decrease from 2018 to 2023 ($APC = -2.0$; 95% CI: $-4.9 - -1.2$) (Table 4).

Table 4 – Number of deaths and age- and sex-standardized mortality rates (per 100,000 inhabitants) of Chagas disease in the Northeast states of Brazil each year (2012-2023).

State	APC1	CI 95%	Period	APC 2	CI 95%	Period	APC 3	CI 95%	Period	Mortality
Maranhão	-3.9	-13.7 – 6.4	2012 - 2023							0.1
Piauí	-3.1	-7.2 – 0.9	2012 - 2023							1.8
Ceará	-16.5	-24.1 – 5.3	2012 – 2014	7.1	3.8 – 16.7	2014 - 2019	-6.1	-14.3 - -2.1	2019 - 2023	0.6
Rio Grande do Norte	2.2	-5.9 – 30.1	2012 - 2021	-30.0	-54.0 - 2.0	2021 - 2023				0.5
Paraíba	1.2	-3.7 – 6.6	2012 - 2023							0.8
Pernambuco	1.0	-7.7 – 28.3	2012 - 2021	-14.8	-34.2 – 3.6	2021 - 2023				1.3
Alagoas	0.5	-5.7 – 11.7	2012 - 2021	-65.5	-77.4 - -38.2	2021 - 2023				2.7
Sergipe	-1.4	-7.0 – 4.6	2012 - 2023							0.9
Bahia	-8.6	-14.1 - 0.9	2012 - 2014	0.6	-8.3 – 8.2	2014 - 2023				4.1
Northeast	-3.8	-7.4 - -1.5	2012 - 2015	1.6	-0.4 – 3.4	2015 -2018	-2.0	-4.9 - -1.2	2018 - 2023	1.8

Legend: APC - Annual percentage change; CI 95% - Confidence interval 95%. Source: Research data (2025).

The global Moran's I for spatial autocorrelation was 0.34 ($p = 0.35$), indicating moderate positive spatial autocorrelation without statistical significance. The map illustrates the geographical distribution of mortality rates in the Northeast (Figure 2B). The LISA analysis identified moderate clusters of high mortality in Alagoas, Bahia, and Pernambuco (Figure 2D and Table 3). In contrast, Sergipe stood out as a robust cluster despite having a lower mortality rate than its neighboring states.

4. Discussion

CD remains a significant public health problem in Latin America (Rassi & Marin-Neto, 2010; Martins-Melo et al., 2012; Pérez-Molina & Molina, 2018), and this study, which analyzed CD-related mortality in the Northeastern region of Brazil between 2012 and 2023, revealed important epidemiological patterns and temporal trends that deserve attention. Rather than solely describing frequency patterns, our analysis contextualizes mortality trends in light of the chronic, socially determined nature of CD in northeastern Brazil.

Although CD control has historically focused on interrupting vector transmission, primarily by eliminating the *Triatoma infestans* vector (Ferreira & Tabosa, 2006; Silveira & Dias, 2011; Cucunubá et al., 2024), the disease can also be transmitted in other ways, such as through blood transfusions, organ transplants, vertical transmission, and even contaminated food. This highlights the importance of strengthening disease notification and monitoring systems to ensure early detection and adequate treatment, along with effective prevention measures. (Does et al., 2020; De Almeida et al., 2021)

Data from this study indicate that most CD-related deaths occurred among men and individuals over 50 years of age. This prevalence among older individuals highlights the chronic nature of the disease, reflecting the long duration between the initial infection and the development of serious complications, such as Chagas cardiomyopathy. (Braga et al., 2006) This underscores the need for long-term follow-up strategies and chronic care protocols, especially for aging cohorts infected decades ago. This pattern was also observed in studies conducted in Colombia, where most deaths occurred in people over 65 years old. (Olivera et al., 2021)

The predominance of the chronic cardiac form as the main cause of death, responsible for 77.5% of cases, underscores the severity of CD cardiac complications, which include arrhythmias and heart failure, both of which have a significant impact on quality of life and patient survival. (Braga et al., 2006; De Almeida et al., 2021; Olivera et al., 2021) This predominance, reinforces the necessity for the Brazilian public health system (SUS) to expand access to diagnostic and therapeutic cardiology services in endemic areas.

The temporal analysis of this study showed an overall downward trend in CD-related mortality, with an annual reduction of approximately 1.5%. This declining trend, observed in six of the nine states in the Northeast region, is consistent with other studies that reported a slow but steady decrease in CD mortality rates in recent years. (Braga et al., 2006; Martins-Melo et al., 2012; Sousa et al., 2020) However, detailed analysis revealed significant variations between states, with Alagoas and Ceará showing a sharp decrease, while Paraíba showed a slight increase in mortality rates. These regional variations reflect the need to tailor public health policies to the specific needs of each location, ensuring more effective and targeted interventions. (Olivera et al., 2020)

The spatial analysis revealed that the states of Bahia, Alagoas, and Pernambuco emerged as areas of high mortality, highlighting the geographic concentration of deaths. This concentration of mortality was confirmed by LISA analysis, which identified moderate clusters of mortality in these areas. These findings are consistent with the study by Goes et al. (2020), which also identified high-risk regions for CD mortality in the state of Sergipe, in the southern part of the region. Such spatial patterns reinforce the need for targeted interventions in these high-mortality areas, aiming to strengthen prevention and treatment strategies.

Another important point highlighted in this study was the association between CD mortality and socioeconomic factors. High mortality among individuals with low educational levels and belonging to vulnerable racial groups, such as Black and Brown people, suggests a strong relationship between socioeconomic vulnerability and the risk of CD mortality. (Braga et al., 2006; Martins-Melo et al., 2012; Sousa et al., 2020) This association was also observed in studies conducted in Colombia, where CD mortality rates were higher among low-income populations with limited access to healthcare services. (Olivera et al., 2020) These socioeconomic disparities underscore the urgent need for public policies that address the social determinants of health and ensure that vulnerable populations have adequate access to the care needed to prevent and treat CD.

Additionally, underreporting should be considered a factor that may impact the interpretation of mortality data. (Dias et al., 2016) Underreporting is a recognized issue, especially in socioeconomically disadvantaged regions, where limited access to healthcare services and diagnostic resources can lead to a significant underestimation of the true burden of the disease. (Olivera et al., 2021) This issue is even more concerning in rural areas, where the presence of the transmitting vector and the difficulty in accessing healthcare services exacerbate the problem. Olivera et al. (2021) also highlighted underreporting as an important factor to consider when interpreting CD mortality data in Colombia, where barriers to diagnostic access directly affect the proper registration of cases.

This study reveals that, despite a slow reduction in CD mortality rates in the Northeast region of Brazil, the disease remains a significant cause of death, particularly in areas with socioeconomic vulnerabilities. The spatial analysis highlighted priority areas, such as Bahia, Alagoas, and Pernambuco, which demand greater attention in control and prevention strategies. More effective and targeted public policies, including health education, strengthened epidemiological surveillance, and improved access to diagnosis and treatment, are essential to further reduce CD mortality. Furthermore, improving notification systems and reducing underreporting are critical to ensuring a more accurate response to the true burden of the disease.

5. Final Considerations

This study provides a comprehensive analysis of Chagas disease-related mortality in Northeastern Brazil from 2012 to 2023, highlighting the persistent public health burden posed by the disease, despite an overall declining trend. The findings reinforce the chronic and socially determined nature of Chagas disease, with mortality disproportionately affecting older adults, males, individuals with low educational attainment, and racially marginalized groups. Spatial analysis further revealed regional disparities, with Bahia, Alagoas, and Pernambuco emerging as consistent hotspots for CD-related deaths.

Although some states demonstrated encouraging declines in mortality, the persistence of high rates in others underscores the need for geographically tailored interventions. These include strengthening surveillance systems, expanding access to timely diagnosis and cardiac care, and addressing the underlying social determinants of health. Public health strategies must also prioritize data quality, particularly through improved notification and reporting practices, to capture the true magnitude of the disease burden.

In conclusion, reducing Chagas disease mortality in the Northeast requires a multifaceted approach that integrates clinical, epidemiological, and social strategies. By focusing on the most vulnerable populations and regions, health authorities can work toward equity in disease prevention and management, ultimately mitigating the impact of Chagas disease on communities across Brazil.

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