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ORIGINAL ARTICLE

Temporal trends and spatial analysis of self-reported autism spectrum disorder in Brazil: a decade of school census insights (2014-2023)

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Objective: To analyze the temporal and spatial trends of children and adolescents reporting a diagnosis of autism spectrum disorder upon school enrollment in Brazil between 2014 and 2023.
Methods: This ecological study employed time series (Mann-Kendall test with Hamed-Rao modification) and spatial analyses (global Moran's *I*). Enrollment data (2014-2023) were obtained from the Brazilian School Census (Censo Escolar), including self-reported autism spectrum disorder.
Results: On a national level, reported autism spectrum disorder cases increased from 8.23 to 134.49 per 10,000 enrolled students ($p < 0.001$; slope ≈ 11.18). Consistent upward trends were also found on a state level (tau = 1, $p < 0.001$), except in São Paulo (tau = 0.78, p = 0.002). The largest and smallest increases were in Acre and São Paulo, respectively. Moran's *I* increased from 0.1235 to 0.3233 (p = 0.001), indicating stronger spatial clustering, with local indicators of spatial association identifying persistent clusters in the southern/southeastern regions and emerging clusters in the northeastern region.
Conclusion: There was a steep nationwide increase in reported autism spectrum disorder cases between 2014 and 2023, with most states trending upward. Spatial clustering strengthened (increase in Moran's *I*), with local indicators of spatial association showing persistent clusters in the southern/southeastern regions and emerging clusters in the northeastern region, which indicates a need for region-specific policies and integrated care.

Keywords: Autism spectrum disorder, epidemiology, Brazil, public health

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental condition whose symptoms manifest during childhood, impairing or limiting an individual's daily functioning.[1] Diagnosis is based on criteria defined in the DSM-V that assess its core characteristics: persistent deficits in reciprocal social communication and interaction plus restricted and repetitive patterns of behavior, interests, or activities.[2] These characteristics vary widely in severity and daily impact, forming the concept of a spectrum. Early diagnosis is pivotal in improving outcomes for children with ASD, providing early intervention opportunities that can improve the quality of life and promote social inclusion for these individuals.[3]

According to the Autism and Developmental Disabilities Monitoring Network, the estimated prevalence of ASD among children 8 years of age has increased markedly in the past 2 decades, from 6.7 per 1,000 (one in 150) in 2000 to 23.0 per 1,000 (one in 44) in 2018,[4] reaching 32.2 per 1,000 (one in 31) in 2022.[5] Studies attribute this increase to extrinsic factors, such as greater awareness and recognition of ASD, changes in diagnostic practices, and improved access to services.[6] However, further research is needed to better understand the epidemiology of ASD in Brazil,[7,8] particularly temporal trends and spatial distribution across the country's five macroregions.

Accurately estimating the demand for ASD services is crucial, given that the 650 support institutions in Brazil,[9] including Child and Youth Psychosocial Care Centers (Centros de Atenção Psicossocial Infantojuvenil) and the Association of Friends of Autistic People (Associação de Amigos do Autista), are unable to fully meet the population's needs. Moreover, these facilities are disproportionately concentrated in the southeastern and southern regions, which are home to 56.5% of the population but account for 85% of all facilities.[9,10]

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This imbalance exacerbates care gaps, delaying essential interventions in underserved areas.

The present study analyzed temporal and spatial trends of ASD in Brazil based on school enrollment data between 2014 and 2023, as recorded in the Brazilian School Census (Censo Escolar).

Methods

Study design

This ecological study involved time series and spatial analyses. The units of analysis were years for the temporal dimension and municipalities for the spatial dimension.

Description of the study area

Brazil is further subdivided into five geographic macroregions (northern, northeastern, midwestern, southeastern, and southern), 26 states, the Federal District, and 5,568 municipalities, though this number varies over time. Despite being one of the world's largest economies, Brazil faces significant social inequality, with a Gini index of 0.543 in 2019.[11]

Data source and definitions

We analyzed enrollment data from the Brazilian School Census between 2014 and 2023. The Brazilian School Census is an annual statistical survey coordinated by the National Institute of Educational Studies and Research Anísio Teixeira (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira) that covers all public and private institutions of basic education nationwide. The 2022 census collected data from 178,300 active schools, documenting 47.4 million enrolled students in 2.2 million classes with 2.3 million teachers.[12] The data were obtained from the School Census Synopsis, an abridged form of School Census data that is publicly available on the Institute's website.[13]

In the School Census, ASD is identified through self-reported information provided during the enrollment process in a specific section on syndromes, diseases, and disabilities. The database nomenclature for ASD underwent a classification change during the study period: from "*autismo*" (autism) between 2014 and 2021 to "*transtorno do espectro autista*" (autism spectrum disorder) beginning in 2022.

To estimate the enrollment rate of students who self-reported an ASD diagnosis, we divided the number of students identified with ASD by the total number of enrolled students. The values are presented in terms of cases per 10,000 (10^4) students. The numerators were obtained from two specific tabs in the School Census Synopsis: data for students with ASD in common classes (tab 1.43 until 2022, tab 1.44 in 2023) and data for students with ASD in exclusive classes (tab 1.49 until 2022, tab 1.50 in 2023). The denominators were obtained from "tab Educação Básica 1.1," which contains all basic education enrollment data.

Temporal trend analysis

To analyze temporal trends in the rate of students with self-reported ASD in Brazil between 2014 and 2023, we employed the Mann-Kendall test with Hamed and Rao modification for autocorrelation, which is suitable for assessing monotonic trends in time series data, even in the presence of serial correlations.[14] The change (%) value quantifies the relative increase in the rate of reported ASD cases between 2014 and 2023. This test was performed to assess temporal trends for each of the 26 states, the Federal District, the five regions (northern, northeastern, midwestern, southeastern, and southern), and the country as a whole.

Spatial analysis

For the spatial analysis, we selected three reference years during the study period (2014, 2019, and 2023) and performed a three-stage analysis.[15]

In the first stage, choropleth maps of the smoothed ASD enrollment rate were generated. Choropleth maps are geographic representations in which each spatial unit (in this case, municipalities) is colored according to the value of a given variable. Here, municipalities were shaded according to their rates smoothed via the local empirical Bayesian method. This approach leverages information from both neighboring municipalities and the broader study region to minimize the influence of random fluctuations, particularly in small-population municipalities where minor variations can otherwise produce disproportionately large rate changes.[16]

The second stage assessed the global spatial dependence of the crude rate using global Moran's *I*, a measure of spatial autocorrelation. This index ranges from -1 to +1, where values close to zero indicate spatial randomness, positive values suggest clustering of similar values, and negative values denote spatial dispersion.

In the third stage, crude rate spatial clusters were identified using local indicators of spatial association based on local Moran's *I*.[17] This method can detect spatial heterogeneity by assessing the degree of similarity or dissimilarity between each municipality and its neighbors. Local Moran's *I* values indicate whether a municipality is part of a cluster of similar values (high-high or low-low) or is a spatial outlier (high-low or low-high). These patterns are derived from the relationship between the standardized value of each observation and the weighted average of its neighboring values, as visualized in the Moran scatterplot. This local-level approach complements global spatial statistics by highlighting specific areas with significant spatial autocorrelation. To ensure robustness, only municipalities with statistically significant local Moran's *I* values ($p < 0.05$) were considered in the final cluster map, enabling a more nuanced understanding of geographic patterns in the enrollment rate of students with ASD.

All spatial analyses were conducted using digital maps provided by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística), ensuring alignment with the study period.

Software

The statistical analysis and data extraction were performed in Python (version 3.12.3) using the pymann-Kendall (version 1.4.3),[18] python-calamine, and esda (2.7.0) libraries.[19]

Ethics statement

Because this study utilized publicly available data aggregated on an administrative level without individual identification, in accordance with Resolution 510/2016, research ethics committee approval was unnecessary.

Results

During the study period, 2,152,552 students who self-reported ASD diagnosis were enrolled in Brazilian basic education institutions, representing 0.45% of all 480,613,906 students enrolled on a national level.

The analysis revealed a marked increase in the enrollment rate of students with a self-reported diagnosis of ASD in Brazil between 2014 and 2023. As illustrated in Figure 1, the national rate rose from 8.23 to 134.49 per 10,000 enrolled students. Temporal statistical analysis (tau = 1, $p < 0.001$) confirmed this upward trend, with an average annual increase of 11.18 cases per 10,000 enrolled students (slope = 11.92).

Figure 2 illustrates the temporal evolution of the enrollment rate of students with a self-reported a diagnosis of ASD across different Brazilian regions and the national aggregate during this period. The southern region had the highest rate in 2023 (161.26/104). The northeastern region had the most substantial relative increase (2,544.72%), followed by the northern region (1,909.78% increase). Despite significant growth, the midwestern region had the lowest rate (114.79/104), followed by the southeastern region (129.01/104), which had the lowest increase (1,067.51%).

Table 1 shows the enrollment rate of students with a self-reported a diagnosis of ASD in individual Brazilian states, regions, and nationwide for 2014 and 2023, accompanied by the trend test results (trend, p, and slope) and relative growth percentages (change). What stands out is the consistent upward trend across all states ($p < 0.001$) with perfect monotonicity (tau = 1.0). São Paulo was the sole exception, showing slightly lower but still substantial monotonicity (tau = 0.78, p = 0.002). Of individual states, Acre had the most pronounced increase, with rates rising from 4.96 to 258.63 per 10,000 enrolled students (a 5,114.31% increase). In contrast, São Paulo had the most moderate growth, with rates increasing from 12.73 to 115.43 per 10,000 enrolled students (an 806.76% increase).

The choropleth analysis revealed a progressive increase in the smooth rate across Brazilian municipalities over time. In 2014 (Figure 3A), ASD cases were predominantly concentrated in a limited number of municipalities, primarily in the southern and southeastern regions. By 2019 (Figure 3B), there was a substantial increase in the number of municipalities with higher rates, with notable increases in the northeastern and northern regions. This trend intensified in 2023 (Figure 3C), when most municipalities reported higher rates than previous years, with the highest concentration remaining in the southern and southeastern regions.

The spatial autocorrelation analysis demonstrated a significant and increasing spatial dependence in ASD enrollment rates over the study period. In 2014, Moran's *I* was estimated at 0.1235 (p = 0.001), indicating weak but

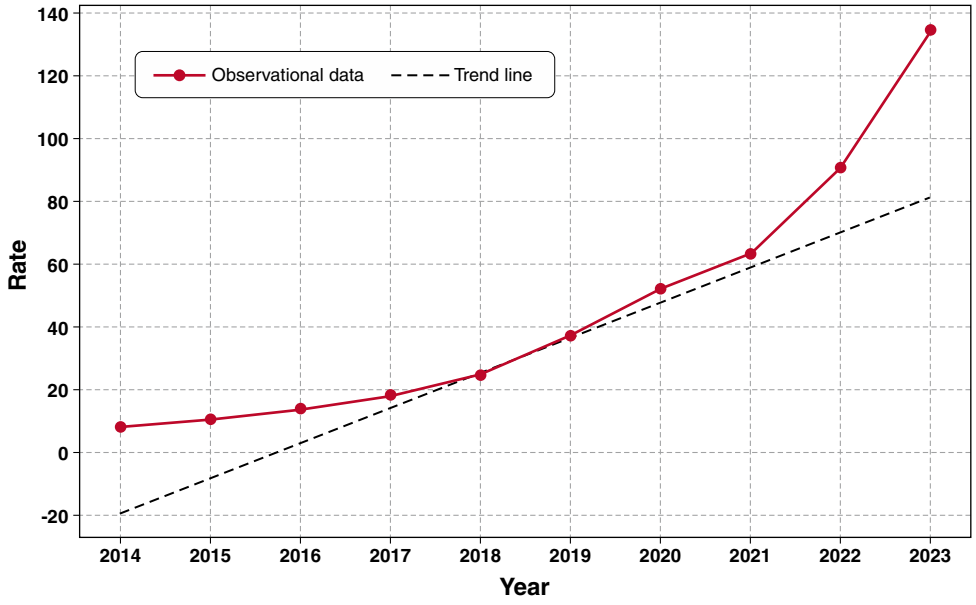


Figure 1 Temporal evolution and trend line of students who reported being diagnosed with autism spectrum disorder per 10,000 enrolled students in Brazil, 2014-2023.

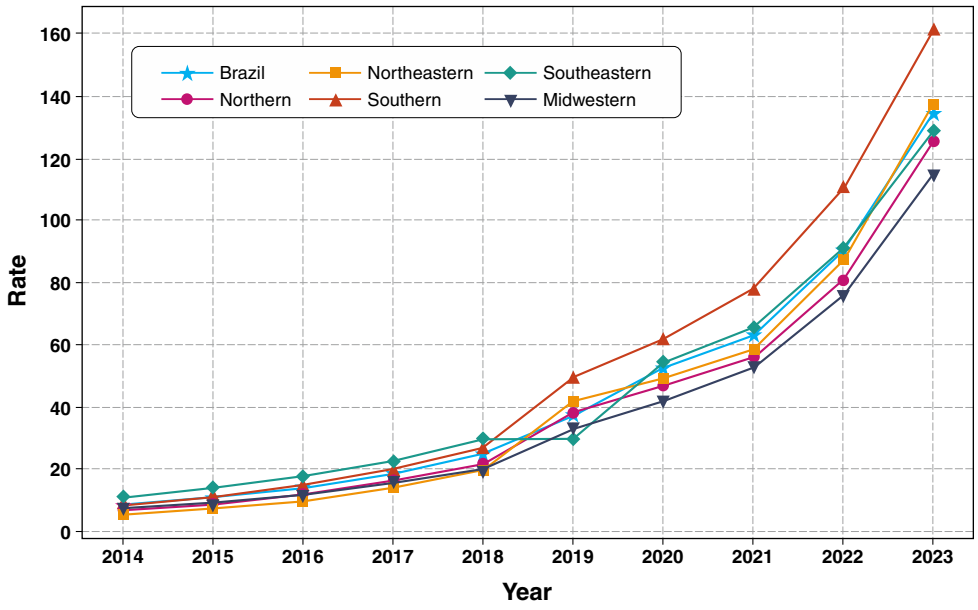


Figure 2 Rate of students who reported being diagnosed with autism spectrum disorder per 10,000 enrolled students in Brazil overall and for each region, 2014-2023.

significant spatial clustering. By 2019, it increased to 0.2886 (p = 0.001), reflecting moderate strengthening of spatial dependence. In 2023, Moran's *I* reached 0.3233 (p = 0.001), suggesting further consolidation of spatial clustering. The consistent positive Moran's *I* values confirm that municipalities with similar ASD enrollment rates tended to be geographically proximate, with an upward trend in spatial structuring over time.

Local indicators of spatial association analysis further delineated the spatial distribution of ASD enrollment rate clusters. In 2014 (Figure 3D), high-high clusters, indicative of municipalities with high rates surrounded by similar areas, were primarily located in the southern and southeastern regions, while low-low clusters, representing areas with consistently lower enrollment rates, were predominant in the northern region and parts of the northeastern region. By 2019 (Figure 3E), the expansion of high-high clusters was evident, particularly in southeastern coastal areas and sections of the northwestern region, with a low-low cluster covering the entirety of São Paulo state. In 2023 (Figure 3F), the spatial clustering pattern became more pronounced, with high-high clusters persisting in the southern and southeastern regions and becoming increasingly evident in Ceará state, which is in the northeastern region. Meanwhile, low-low clusters remained concentrated in the northern region and inland areas of the northeastern regions.

Discussion

This study identified a national rate of 134.49 cases per 10,000 enrolled students (1.34%). This is higher than global estimates, which range from 0.4%[20] to 0.6%, with previous subgroup analysis indicating prevalence of 0.4% in Asia, 1% in North America, 0.5% in Europe, 1% in Africa, and 1.7% in Australia.[21] The prevalence was 3.66% in Sweden, 2.76% in the United States, 1.55% in Spain, 1.15% in Greece, 0.87% in Mexico, 0.36% in Asia, 0.06% in Iran, 2.69% in South Korea, and 0.17% in Venezuela.[4,21-27] It is important to highlight methodological differences in the above mentioned studies, particularly regarding case definition, data sources, sample size, and inclusion/exclusion criteria, which could limit the comparability of these prevalence rates.[28] Moreover, our study did not estimate the clinical incidence or prevalence of ASD, but rather the enrollment rate of students with a self-reported diagnosis of ASD, which reflects administrative records from school enrollment data and could be influenced by many factors to be discussed below.

In Brazil, ASD rates increased 16.34 times between 2014 and 2023 and tripled between 2019 and 2023, which was higher than in other regions during similar periods (e.g., a 7-fold increase in England, a 5-fold increase in Asia, and a 4-fold increase in the USA).[4,29-32] These findings may reflect evolving diagnostic criteria,[2] public awareness, access to services, overdiagnosis[28,33] and pandemic-related shifts, including remote assessments and delayed notifications between 2020 and 2022.[34]

Nevertheless, the observed progression may be partly explained by improved educational levels and increased access to online information in Brazil, especially in urban areas.[35] Additionally, the country's demographic transition and significant advances in medical technology, which have improved the survival rates of children with early childhood events, such as prematurity, cesarean delivery, low birth weight, low Apgar score, and hypoxia, may have also contributed to this trend.[36-40] Finally, we point out that Brazil's current economic condition and advancement in ASD-related policies, such as Law No.

Table 1 Enrollment rate of students who reported being diagnosed with autism spectrum disorder (2014 and 2023) and rate trends (2014 to 2023) in Brazilian regions and states

	Rate per 10,000		Trend test results			
	2014	2023	Trend	p-value*	Slope	Change (%)
Brazil	8.23	134.49	↑	> 0.001	11.18	1534.14
Distrito Federal	15.74	128.31	↑	> 0.001	10.98	715.18
North	6.24	125.41	↑	> 0.001	9.35	1909.78
Acre	4.96	258.63	↑	> 0.001	21.09	5114.31
Amapá	9.37	233.14	↑	> 0.001	17.72	2388.15
Amazonas	7.01	103.10	↑	> 0.001	7.95	1370.76
Pará	5.91	107.81	↑	> 0.001	7.81	1724.2
Rondônia	6.12	156.78	↑	> 0.001	12.60	2461.76
Roraima	5.57	131.68	↑	> 0.001	9.29	2264.09
Tocantins	5.46	110.75	↑	> 0.001	9.62	1928.39
Northeast	5.21	137.79	↑	> 0.001	10.71	2544.72
Alagoas	4.55	99.26	↑	> 0.001	7.76	2081.54
Bahia	4.25	110.09	↑	> 0.001	9.29	2490.35
Ceará	6.2	207.23	↑	> 0.001	14.99	3242.42
Maranhão	3.96	106.06	↑	> 0.001	08.01	2578.28
Paraíba	5.18	150.47	↑	> 0.001	11.25	2804.83
Pernambuco	5.18	139.33	↑	> 0.001	11.32	2589.77
Piauí	8.34	159.04	↑	> 0.001	13.21	1806.95
Rio Grande do Norte	6.28	145.09	↑	> 0.001	11.64	2210.35
Sergipe	6.61	142.74	↑	> 0.001	9.99	2059.46
Midwest	7.24	114.79	↑	> 0.001	8.92	1485.50
Goiás	5.16	108.43	↑	> 0.001	7.86	2001.36
Mato Grosso	5.28	114.45	↑	> 0.001	9.68	2067.61
Mato Grosso do Sul	5.81	116.25	↑	> 0.001	10.20	1900.86
Southeast	11.05	129.01	↑	> 0.001	10.69	1067.51
Espírito Santo	11.30	217.39	↑	> 0.001	19.43	1823.81
Minas Gerais	9.18	134.47	↑	> 0.001	10.65	1364.81
Rio de Janeiro	8.72	139.58	↑	> 0.001	12.25	1500.69
São Paulo	12.73	115.43	↑	0.020	9.20	806.76
South	8.73	161.26	↑	> 0.001	14.00	1747.19
Paraná	5.70	141.57	↑	> 0.001	12.36	2383.68
Rio Grande do Sul	10.8	155.13	↑	> 0.001	13.57	1336.39
Santa Catarina	10.64	197.43	↑	> 0.001	17.56	1755.55

↑ = increasing.
* All analyses were significant at a 0.05 level.

12,764/2012 (the Berenice Piana Law), which includes social guarantees and health, education, transportation, and employment benefits, help facilitate access to health and educational services for families, and likely influence whether individuals seek help upon noticing early signs and symptoms of the disorder.[41-45]

We found significant regional disparities in ASD reporting in Brazil. Spatial analysis revealed dynamic and evolving geographic clustering, marked by a progressive increase in spatial dependence, as evidenced by rising Moran's *I* values over time. This indicates that ASD reporting is becoming increasingly concentrated in specific regions, with certain municipalities forming persistent high-reporting clusters, while others may consistently underreport. These patterns reflect regional inequalities in access to diagnostic services, inclusive education policies, and local administrative capacities. Rather than being randomly distributed, ASD reporting appears to be shaped by underlying regional dynamics, such as structural, socioeconomic, and institutional differences throughout the country.[46]

As an example, the southern and southeastern regions, which are characterized by high urbanization and advanced health care, have higher diagnosis rates, while lower diagnosis rates occur in the northern and northeastern regions due to lower socioeconomic development and less urbanization. Although the pathogenesis of ASD involves epigenetic interactions between genetic and environmental factors, such as parental age, prenatal exposure, perinatal risks, maternal medication, and socioeconomic status,[40] the link between socioeconomic class and ASD prevalence remains controversial.[47] While low-income regions may have greater risk factors related to pre- and postnatal conditions,[48] high-income regions might have a higher ASD prevalence due to genetic factors and older parents.[46] Based on our data, we hypothesize that the higher incidence of ASD in high-income populations is due to underdiagnosis in low-income areas, a disparity driven primarily by differences in health care access.

This study draws on a whole-population dataset from a nationwide school census, with fine-grained information

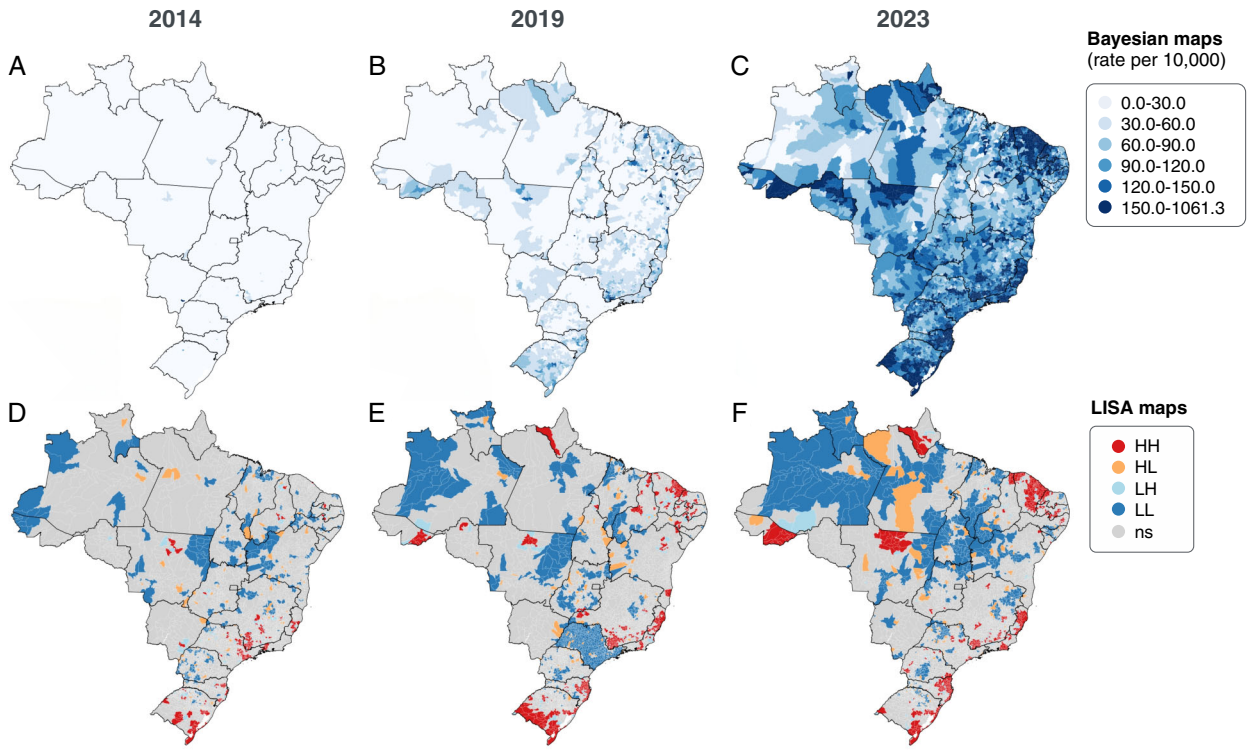


Figure 3 A, B, and C) Bayesian choropleth maps, and D, E, and F) LISA maps showing the distribution of students who reported being diagnosed with autism spectrum disorder across Brazilian municipalities in 2014, 2019, and 2023. HH = high-high; HL = high-low; LH = low-high; LISA = local indicators of spatial association; LL = low-low; ns = not significant.

available at the municipality level and spatial analysis of ASD reporting data across Brazilian municipalities. This provided an expressive sample size and strengthened the robustness of the findings. However, key limitations include Brazil's inclusive education policy, which allows students to self-report ASD without providing evidence of a clinical diagnosis, which could increase the number of participants but also introduce bias.[49]

In addition, because the School Census counts the number of enrollments rather than unique individuals, a single individual could have been counted multiple times in different years, potentially inflating the observed trends and spatial clusters – particularly in smaller municipalities. ASD reporting is also voluntary and may be influenced by regional heterogeneity in health care access, education systems, and cultural perceptions, introducing bidirectional bias. Finally, school closures during the COVID-19 pandemic, especially between 2020 and 2021, likely affected both enrollment numbers and reporting practices, given that data collection was constrained during this period, as also noted in other studies,[50,51] adding further uncertainty to the data for those years.

In conclusion, our findings indicate a significant increase in students who reported being diagnosed with ASD in Brazil between 2014 and 2023, with notable regional disparities. The southern and southeastern regions consistently had the highest reporting rates, likely reflecting greater availability of specialized services and diagnostic access. In contrast, there were substantial relative increases in the northern and northeastern regions, which could be attributable to both improved ASD identification and persistent challenges in accessing specialized support.

Spatial analysis revealed evolving geographic clustering patterns in ASD reporting, with a progressive increase in spatial dependence, as evidenced by the rising Moran's *I* index. This suggests that disparities in diagnosis and access to support services are becoming more pronounced across municipalities.

These findings underscore the urgent need for policies aimed at ensuring equitable distribution of ASD-related services and strengthening public strategies for diagnosis and educational inclusion. Future research should integrate clinical and epidemiological data to validate these observed trends and contribute to more effective and inclusive policy interventions.

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necessary data and contributed significantly to the development of this study.

Disclosure

The authors report no conflicts of interest.

Data availability statement

The data that support this study are available on the website of Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, and is also referenced in the list.[13]

Author contributions

LGSF: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Writing – Original Draft, Writing – Review & Editing.
GSBA: Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft, Writing – Review & Editing, Visualization.
PBSJ: Formal analysis, Investigation, Writing – original draft, Writing – Review & Editing.
RCM: Conceptualization, Writing – original draft, Writing – Review & Editing.
VEAR: Conceptualization, Writing – original draft.
MHFA: Investigation, Writing – original draft, Writing – Review & Editing.
GPO: Conceptualization, Methodology, Supervision, Validation, Writing – Review & Editing.
All authors have read and approved of the final version to be published.

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