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An interrupted time series study of the leprosy case detection in Brazil after the COVID-19 pandemic

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COVID-19 pandemics affected several health systems processes, including leprosy care. This study aimed to estimate the impact of the COVID-19 pandemic on the leprosy case detection rate in Brazil from 2017 to 2022. Data was retrieved from Sinan, a Brazilian notification system, and monthly leprosy detection rate in the overall population and in individuals under 15 years of age were the main outcomes. The series was interrupted in February 2020, when the COVID-19 public health emergency was declared in Brazil. The data were analysed via Prais–Winsten regression. Over the 72 months analysed, the COVID-19 pandemic led to an immediate 0.55 reduction (95% CI 0.48–0.62) in the overall leprosy detection rate, with a subsequent monthly increase of 1.01 (95% CI 1.00–1.02). For the population under 15 years of age, the pandemic caused an immediate 0.48 reduction (95% CI 0.40–0.57), followed by a monthly increase of 1.01 (95% CI 1.01–1.02) after the onset of the pandemic. Subnational analysis revealed that most federative units followed the trend for the overall detection rate, but high heterogeneity was observed regarding individuals under 15 years of age. Therefore, it is urgent to target strategies to minimize delayed diagnosis and long-term consequences of leprosy.

Keywords Hansen's disease, Leprosy, COVID-19, Interrupted time series analysis, Epidemiology

Leprosy is a chronic infectious disease caused by the intracellular bacilli *Mycobacterium leprae* or *Mycobacterium lepromatosis*, resulting in neurological and dermatological symptoms in infected individuals[1,2]. Despite being an ancient and treatable disease, leprosy remains a public health issue, particularly among vulnerable populations[3,4].

Since the introduction and global distribution of multidrug therapy, known as polychemotherapy (PQT-U, in Portuguese), significant progress has been made in reducing the prevalence of leprosy and detecting new cases. Global strategies have been implemented, and the number of new cases decreased by 19.3% between 2013 and 2022, with a notable reduction of 6% up to 2019[5].

Nevertheless, Brazil ranks second worldwide in terms of new leprosy cases, with 22,773 new cases reported in 2023, 958 of which occurred in individuals under 15 years of age. According to the 2025 epidemiological bulletin on leprosy in Brazil, several municipalities in the North, Northeast, and Midwest Regions are considered hyperendemic (≥ 40.0 cases/100,000 population), whereas those in the Southeast and South Regions are categorized as having medium, low, or no cases (≤ 9.9 cases/100,000 population). With respect to the detection rate among individuals under 15 years of age, municipalities in the Midwest and North Regions are the most hyperendemic (≥ 10.0 cases/100,000 population). The number of individuals with late diagnoses is concerning, as 2,173 individuals were diagnosed with grade 2 physical disability (G2D) at the time of diagnosis[6]. Partial data from the leprosy monitoring panel in Brazil indicate that, as of the submission of this article, Brazil had already diagnosed 19,469 new cases of the disease, including 796 in individuals under 15 years old. Additionally, 1,944 cases have already been diagnosed with G2D[7].

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Among the key epidemiological indicators for monitoring this disease, the overall detection rate and the detection rate among individuals under 15 years of age stand out. The overall detection rate can be used as a proxy for incidence in the context of a chronic disease and helps to understand the morbidity, burden, magnitude, and trend of an endemic disease. Conversely, the detection rate among individuals under 15 years of age is considered an indicator of recent transmission in the community due to the long incubation period of the bacillus[5]. Thus, evaluating these indicators aids in understanding the chain of transmission and the operational capacity of health services.

Like many other areas, leprosy surveillance actions were affected by the COVID-19 pandemic. In Brazil, the pandemic was declared in March, 2020 and became one of the greatest local public health challenges. Since COVID-19 (SARS-CoV-2) is transmitted via respiratory routes, social distancing measures were implemented, leading to the suspension of regular health services at the local level. The density of the Brazilian population, combined with the challenges imposed by the COVID-19 pandemic, pushed the Brazilian Unified Health System (SUS) to its limit[8].

In this context, nonurgent outpatient services and hospital admissions were discouraged to prevent the spread of COVID-19. Additionally, measures to reduce transmission posed a threat to leprosy control efforts by impacting the diagnosis of new cases, the treatment of existing cases, and consequently, surveillance and control[9].

Therefore, understanding the impact of the pandemic on leprosy detection and observing trends in these indicators throughout the public health emergency are crucial for developing public policies[10]. For example, in February 2024, the Brazilian government instituted the Healthy Brazil Program (Brasil Saudável, in Portuguese), an interministerial initiative aimed at eliminating socially determined diseases, including leprosy, as a public health problem[11].

Given this rationale, it is essential to monitor the leprosy case detection in Brazil, the most populous country in South America and the country with the second highest rate of leprosy worldwide. As Brazil has continental dimensions, national and subnational estimates provide an even more detailed overview of the epidemiologic profile of the disease. Additionally, given the COVID-19 impact on health and surveillance systems, analysing the post-pandemic rates of leprosy, a tropical neglected disease, can benefit public health by improving resilient health systems, providing evidence to decision-making, public policy development, and resources allocation. Therefore, the aim of this study was to estimate the impact of the COVID-19 pandemic on the change in leprosy case detection in Brazil from 2017 to 2022.

Methods

Study design

This was an interrupted time series study. Interrupted time series studies are one of the best study designs for evaluating an intervention or event to establish a relationship between the event and the observed data[12–14].

The study was conducted using data from Brazil, its regions, and federative units as the units of analysis. Brazil is a very large country with a territorial area of 8,510,417 km^2 and a population of 203,080,756 inhabitants, resulting in a population density of 23.86 inhabitants/km^2. The country is composed of 5570 municipalities organized into 27 federative units (26 states and one Federative District), which are grouped into five major regions: the North Region, Northeast Region, Southeast Region, South Region, and Midwest Region (Fig. 1A).

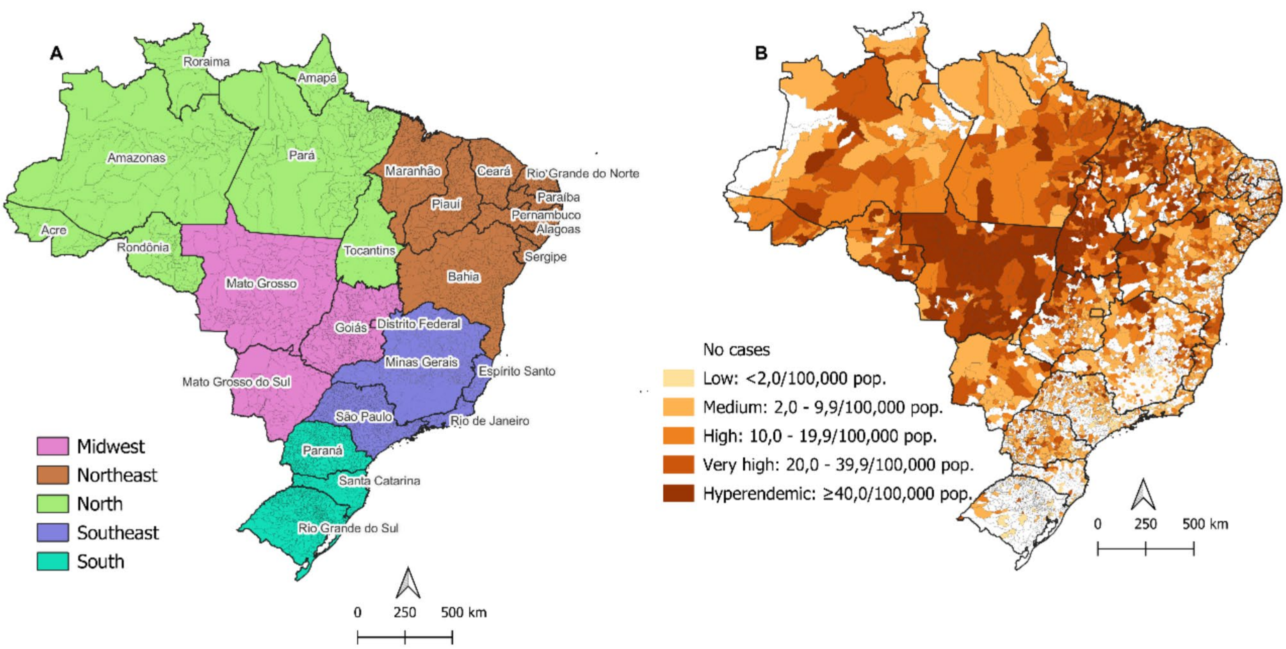

Fig. 1. Distribution of Brazilian regions and Federative Units and leprosy detection rates.

The country is characterized by significant inequality in terms of income concentration and social vulnerability. The Southeast and South Regions have higher incomes and better indicators of education, human development, and longevity. The distribution of leprosy in Brazil is shown in Fig. 1B.

Procedures

The Brazilian Information System of Notifiable Diseases (Sinan) for leprosy notifications was the data source used in this study. This data are collected via mandatory notification forms, where the healthcare professional who first treats the patient completes the items related to the patient's sociodemographic, clinical, and epidemiological characteristics. Annually, data from the databases of municipalities, federative units, and the Brazilian Ministry of Health are consolidated to understand the epidemiological characteristics of people affected by leprosy. Notably, these data are freely distributed to the public via the SUS Information Technology Department (DATASUS) website (https://datasus.saude.gov.br/).

Study outcomes

For this study, two outcomes were adopted: (1) the overall leprosy detection rate per 100,000 population and (2) the leprosy detection rate among individuals under 15 years of age per 100,000 population. For both detection rates, the number of new monthly cases from January 2017 to December 2022 was obtained from Sinan-Leprosy. The purpose of the analyses for these two outcomes is not to compare groups but rather to demonstrate how health systems have managed to address leprosy in the Brazilian population as a whole and in the pediatric population.

For the population estimates, data from the Brazilian Institute of Geography and Statistics (IBGE, in Portuguese) were used for the period from 2017 to 2021. Data for the population in 2022 was obtained from the Brazilian Demographic Census conducted in that year.

With these data, a monthly indicator was created using the population for the respective year, multiplied by a constant of 100,000 population, resulting in a total of 72 data points over time. The detection rate among individuals under 15 years of age was calculated via the same method, considering the specific age group under analysis.

The event responsible for the interruption of the time series of interest in this study was the COVID-19 public health emergency declared by Law No. 13,979 of February 6, 2020[15]. In this context, January 2017 to February 2020 was considered the "preintervention" period, and March 2020 to December 2022 was considered the "postintervention" period.

To adjust for temporal effects, three variables were added: one variable for trend and two variables for seasonality. The trend variable was included as a sequential numerical term ranging from 1 to 72, representing the time since the beginning of the series during which the data were collected. The two additional variables accounted for possible seasonal variations in the outcomes analysed through a Fourier term that included sine and cosine components of the studied period[16,17]. Although leprosy does not exhibit seasonal variation, this term was included because of the increase in the number of cases in the first half of each year, generally driven by neglected tropical disease detection campaigns.

To analyse the pandemic effect, two variables were included: the level-change and trend-change variables. The level-change variable was a binary variable that assumed a value of 0 in the preintervention period and 1 in the postintervention period. The trend-change variable had a value of 0 in the preintervention period and a value starting from 1 for the postintervention period[18].

Statistical analysis

For data analysis, Prais–Winsten regression was performed, assuming first-order serial autocorrelation in the model[19]. Additionally, the outcome data were analysed via base-10 logarithms. Next, the results from the coefficients of the level-change and trend-change variables were exponentiated for better interpretation and presented as measures of impact. Values > 1.0 indicated an increase in the level and/or trend, whereas values < 1.0 indicated a decrease in the level and/or trend.

Coefficient trends were considered to increase when the regression coefficient was significantly positive and decrease when the coefficient was statistically negative. The series was considered stationary at $p > 0.05$. For these estimates, 95% confidence intervals (95% CI) were also calculated[18].

The data are presented graphically along with a line representing the expected detection rate calculated via generalized least squares regression. This line of expected results was included solely for graphical purposes as a counterfactual to the study findings. Note that the graphical results are presented as a straight line, excluding the seasonal components, to improve visualization of the events under study.

To assess model fit, the Durbin–Watson test was conducted. The Durbin–Watson statistic ranges from 0.0 to 4.0, with values close to 2.0 indicating the absence of autocorrelation. Conversely, extreme values suggest that other orders of autocorrelation should be considered in the data analysis process[19]. Additionally, the adjusted R^2 value was analysed to determine whether the terms included in the regression sufficiently described the model, with values closer to 1.0 indicating a better fit.

For each outcome, the analysis was conducted at the national, regional, and federative unit levels. The data were tabulated and analysed via R software version 4.3.2 (R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria (https://www.R-project.org/). As secondary and freely accessible data were used, the study did not require prior approval from an ethics committee, as stated by the Brazilian Health Council.

Results

Overall detection rate

During the 72 months analysed, 139,876 new cases of leprosy were reported in Brazil. The country had an average of 2321 cases detected monthly before the pandemic (1.1 cases per 100,000 population) and 1520 cases detected monthly after the pandemic (0.7 cases per 100,000 population). This decline in the number of cases and detection was similar across all regions of Brazil, as well as in their respective federative units (Supplementary File 1).

The onset of the COVID-19 pandemic impacted the detection rate at the national level, leading to an immediate 0.55 reduction in its value (95% CI 0.48–0.62). In the subsequent months, there was an average increase in this rate of 1.01 per month after the pandemic began (95% CI 1.00–1.02) (Fig. 2A; Table 1).

In all regions, an immediate impact of the COVID-19 pandemic on the leprosy detection rate was observed. The North and Northeast Regions experienced similar effects, with reductions of 0.56 (95% CI 0.47–0.66) and 0.55 (95% CI 0.48–0.64), respectively. Both regions showed a progressive increase of 1.02 per month after the onset of the pandemic (Fig. 2B, C; Table 1).

Conversely, the Southeast and South regions were less affected by the pandemic, with reductions of 0.65 (95% CI 0.58–0.74) and 0.68 (95% CI 0.60–0.77) in the detection rate, respectively. These regions demonstrated a statistically significant increase of 1.01 per month after the start of the COVID-19 pandemic (Fig. 2D, E; Table 1).

Finally, the greatest impact of the COVID-19 pandemic was observed in the Midwest Region, with an immediate decrease of 0.46 (95% CI 0.38–0.55). However, this region was the only region that exhibited a stationary detection rate throughout the pandemic period (Fig. 2F; Table 1). The regression fit indices are presented in Table 1.

The stratified analysis of the impact of the pandemic in the federative units revealed that most of them showed the same pattern as their respective regions. All states in the North Region experienced a decline in the monthly detection rate at the onset of the pandemic, with Amapá (impact = 0.33; 95% CI 0.20–0.57) and Tocantins (impact = 0.42; 95% CI 0.35–0.51) having the sharpest drops. In the Northeast Region, the most evident level changes were observed in Pernambuco (impact = 0.45; 95% CI 0.37–0.55) and Maranhão (impact = 0.50; 95% CI 0.41–0.62). In the Southeast Region, all federative units had a significant level change, especially Espírito Santo (impact = 0.47; 95% CI 0.39–0.56). In the South Region, only Paraná exhibited a significant level-change pattern (impact = 0.71; IC 95%: 0.60–0.84). Finally, in the Midwest Region, Mato Grosso showed the greatest decline (impact = 0.41; 95% CI 0.33–0.51) (Table 1).

With respect to trend changes, in the North Region, Acre and Roraima presented a significant increase in the monthly detection rate following the onset of the pandemic. In the Northeast Region, Maranhão, Piauí, Pernambuco, Alagoas, Sergipe, and Bahia presented similar trends. In the Southeast Region, the detection rates of all four states increased after the initial decline. Other states across the country exhibited a stationary trend in new leprosy case detection. All the models demonstrated no evidence of serial autocorrelation in the residuals (Table 1; Supplementary Files 2–6).

Detection rate in individuals aged < 15 years

Over the 72-month evaluation period, 7,422 new cases of leprosy in individuals under 15 years of age were reported in Brazil. The country had an average of 136 new cases per month before the pandemic (0.3 cases/100,000 population) and 66 cases per month after the onset of the pandemic (0.2 cases/100,000 population). A similar pattern was observed in the Brazilian federative units (Supplementary File 7).

Regarding the interrupted time series analysis, Fig. 3 shows the change in the detection rate of leprosy in individuals under 15 years of age. In Brazil, the pandemic resulted in an immediate 0.48 reduction (95% CI 0.40–0.57) in the detection rate for this age group, with a 1.01 increase per month (95% CI 1.01–1.02) after the pandemic began (Fig. 3A; Table 2). In the North Region, a 0.45 decrease (95% CI 0.31–0.55) in the detection rate of leprosy in individuals aged < 15 years was observed following the onset of the pandemic, and the rate showed a stationary pattern (Fig. 3B; Table 2). In the Northeast Region, the pandemic led to a 0.44 reduction (95% CI 0.35–0.55) in new cases in this age group, with a 1.02 increase per month (95% CI 1.02–1.03) (Fig. 3C; Table 2).

In the Southeast Region, there was an immediate 0.67 reduction (95% CI 0.45–0.99) in the detection rate among individuals aged < 15 years due to the pandemic, with the trend remaining stationary after the pandemic began (Fig. 3D; Table 2). In the South Region, there was no significant change due to the pandemic (Fig. 3E; Table 2). Finally, in the Midwest Region, the pandemic led to a 0.43 reduction (95% CI 0.33–0.57) in the monthly detection rate, with a stationary pattern throughout (Fig. 3F; Table 2).

In contrast to the overall detection rate, analysis stratified by federative unit revealed heterogeneous trends in the detection rate among individuals under 15 years of age. With respect to level change, in the North Region, decreases in the detection rate were observed in Pará (impact = 0.59; 95% CI 0.42–0.83) and Tocantins (impact = 0.26; 95% CI 0.16–0.43). In the Northeast Region, significant decreases were observed in Maranhão (impact = 0.47; 95% CI 0.33–0.67), Piauí (impact = 0.59; 95% CI 0.35–0.98), Ceará (impact = 0.50; 95% CI 0.26–0.95), Pernambuco (impact = 0.38; 95% CI 0.27–0.53), and Bahia (impact = 0.31; 95% CI 0.19–0.50). In the Southeast Region, a level change was observed in Minas Gerais (impact = 0.41; 95% CI 0.24–0.71), and in the Midwest Region, a level change was observed in Mato Grosso (impact = 0.43; 95% CI 0.33–0.57). No level changes were observed in the South Region.

With respect to the trend change, the detection rate in the state of Acre decreased by 0.99 over the course of the pandemic. In the Northeast Region, the detection rates in the states of Maranhão, Piauí, Pernambuco, and Bahia slightly increased during the pandemic. In the South Region, Santa Catarina exhibited a 0.95 (95% CI 0.91–0.99) decrease in the detection rate among individuals under 15 years of age after the onset of the pandemic. No trend changes were observed in the Southeast and Midwest regions during the pandemic (Table 2; Supplementary Files 8–12).

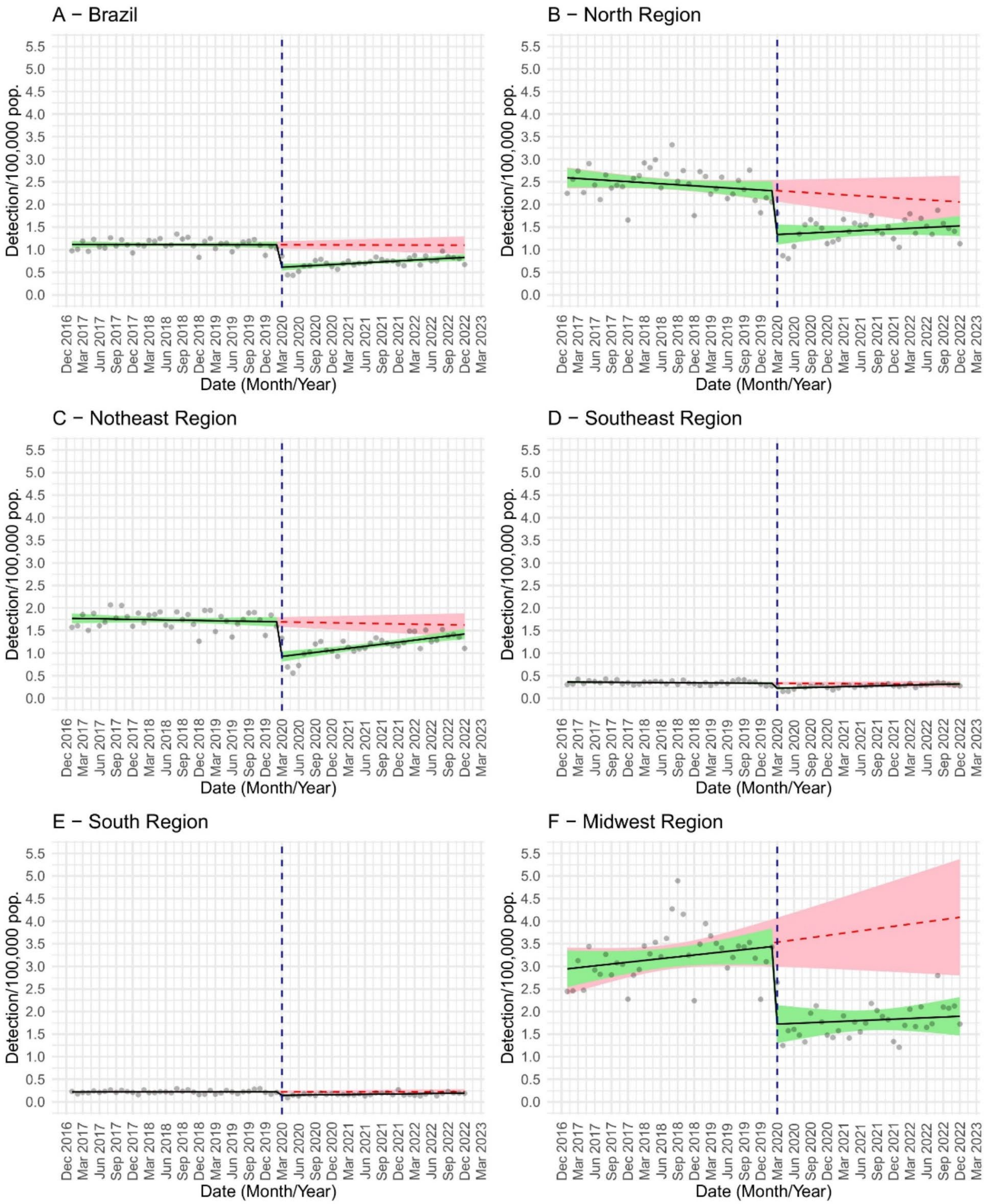

Fig. 2. Temporal Pattern of the Monthly Leprosy Detection Rate Before and After the COVID-19 Pandemic in Brazil and its Regions, 2017–2022. *Note*: Points represent the observed rates; the solid line represents the modelled and adjusted detection rates without the seasonal component; the dashed line represents the counterfactual of expected cases; and the vertical dashed line represents the pandemic milestone.

Discussion

This study identified the impact of the COVID-19 pandemic on the overall leprosy detection rate and on the rate among the population under 15 years of age in Brazil. The results were consistent across the regions and federative units in Brazil. Additionally, there was a slow resumption in the detection of cases. Overall, these

	Level change		Trend change			
	Impact	95% CI	Impact	95% CI	Durbin-Watson	R^2
Brazil	0.55***	0.48–0.62	1.01**	1.00–1.02	1.94	0.757
North Region	0.56***	0.47–0.66	1.01*	1.00–1.02	1.93	0.683
Rondônia	0.58*	0.40–0.84	1.02	0.99–1.04	1.92	0.295
Acre	0.66*	0.44–0.97	1.03***	1.02–1.06	1.96	0.171
Amazonas	0.84**	0.40–0.58	1.02	0.99–1.04	1.92	0.294
Roraima	0.47*	0.26–0.84	1.04**	1.02–1.07	1.93	0.412
Pará	0.65***	0.54–0.78	1.00	0.99–1.01	1.96	0.631
Amapá	0.33***	0.20–0.57	1.00	0.98–1.03	1.99	0.364
Tocantins	0.42***	0.35–0.51	1.00	0.99–1.01	1.99	0.756
Northeast Region	0.55***	0.48–0.64	1.02***	1.01–1.02	1.91	0.667
Maranhão	0.50***	0.41–0.62	1.02**	1.01–1.03	1.90	0.560
Piauí	0.56***	0.43–0.73	1.03***	1.02–1.04	1.98	0.464
Ceará	0.67***	0.55–0.82	1.00	0.99–1.02	1.94	0.443
Rio Grande do Norte	0.86	0.61–1.20	1.02	0.99–1.03	1.99	0.083
Paraíba	0.52***	0.40–0.67	1.00	0.99–1.02	1.98	0.378
Pernambuco	0.45***	0.37–0.55	1.02**	1.01–1.03	1.91	0.575
Alagoas	0.63**	0.47–0.83	1.02*	1.00–1.03	1.95	0.173
Sergipe	0.72**	0.58–0.90	1.02**	1.01–1.03	2.03	0.384
Bahia	0.57***	0.50–0.65	1.02***	1.01–1.02	1.95	0.710
Southeast Region	0.65***	0.58–0.74	1.01***	1.01–1.02	1.97	0.629
Minas Gerais	0.62***	0.53–0.72	1.02***	1.01–1.03	1.98	0.516
Espírito Santo	0.47***	0.39–0.56	1.02***	1.01–1.02	2.01	0.638
Rio de Janeiro	0.64***	0.52–0.79	1.01*	1.00–1.02	1.96	0.476
São Paulo	0.78**	0.66–0.91	1.01**	1.00–1.02	1.99	0.303
South Region	0.68***	0.60–0.77	1.01**	1.00–1.01	2.01	0.650
Paraná	0.71***	0.60–0.84	1.00	0.99–1.01	2.01	0.551
Santa Catarina	0.77	0.51–1.16	1.00	0.99–1.03	2.00	0.647
Rio Grande do Sul	0.85	0.48–1.51	1.00	0.98–1.03	1.99	−0.05
Midwest Region	0.46***	0.38–0.55	1.00	0.99–1.01	1.95	0.703
Mato Grosso do Sul	0.58**	0.42–0.82	1.00	0.98–1.01	1.98	0.318
Mato Grosso	0.41***	0.33–0.51	1.00	0.99–1.01	1.98	0.691
Goiás	0.61***	0.52–0.71	1.01	1.00–1.01	2.00	0.662
Distrito Federal	0.67	0.43–1.05	1.00	0.97–1.02	1.97	0.001

Table 1. Interrupted time series analysis of the monthly impact of the pandemic on the leprosy case detection rates in Brazilian Federative Units, 2017–2022. 95% CI: 95% confidence interval; R^2: adjusted R-squared; $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$.

results demonstrate that while there was an immediate decline in case detection, a slow and gradual return to pre-pandemic levels has been observed. However, the decrease in case detection and the lack of recovery in some regions may worsen the epidemiological situation of leprosy in the country, as cases are not having adequate treatment and continue to actively transmit the disease.

The impact of the pandemic was not only observed in the temporal patterns of leprosy. Studies have shown that the COVID-19 pandemic also negatively affected the detection of other transmissible diseases, such as tuberculosis[20], visceral leishmaniasis[21], hepatitis C[22], and schistosomiasis[23], as well as non-communicable chronic diseases[24,25]. This highlights the global impact of COVID-19 on the organization of health services, particularly in health surveillance and the capacity to respond to a pandemic. However, most of the published studies focus only on the immediate impact and do not consider the long-term effects.

The interruption of health services following the onset of the pandemic may have led to a decrease in the detection of new leprosy cases. The focus and resources redirected to combating COVID-19 diminished the capacity of the healthcare system to manage other diseases, such as leprosy[8]. This scenario could result in fewer people seeking treatment and fewer healthcare professionals being available to diagnose and treat cases of leprosy, resulting in a reduced number of leprosy diagnoses. A similar result was found in an leprosy-endemic province in China, where there was a marked reduction in diagnoses in 2020[26], a phenomenon observed in various parts of the world. This underscores the neglected nature of chronic diseases, particularly leprosy.

After the onset of the pandemic, there was a reduction in active case-finding activities, contact evaluations, and other surveillance activities, which may have affected the detection of new leprosy cases[27]. The variation in the impact patterns of the pandemic across Brazilian regions is consistent with the existing geographic

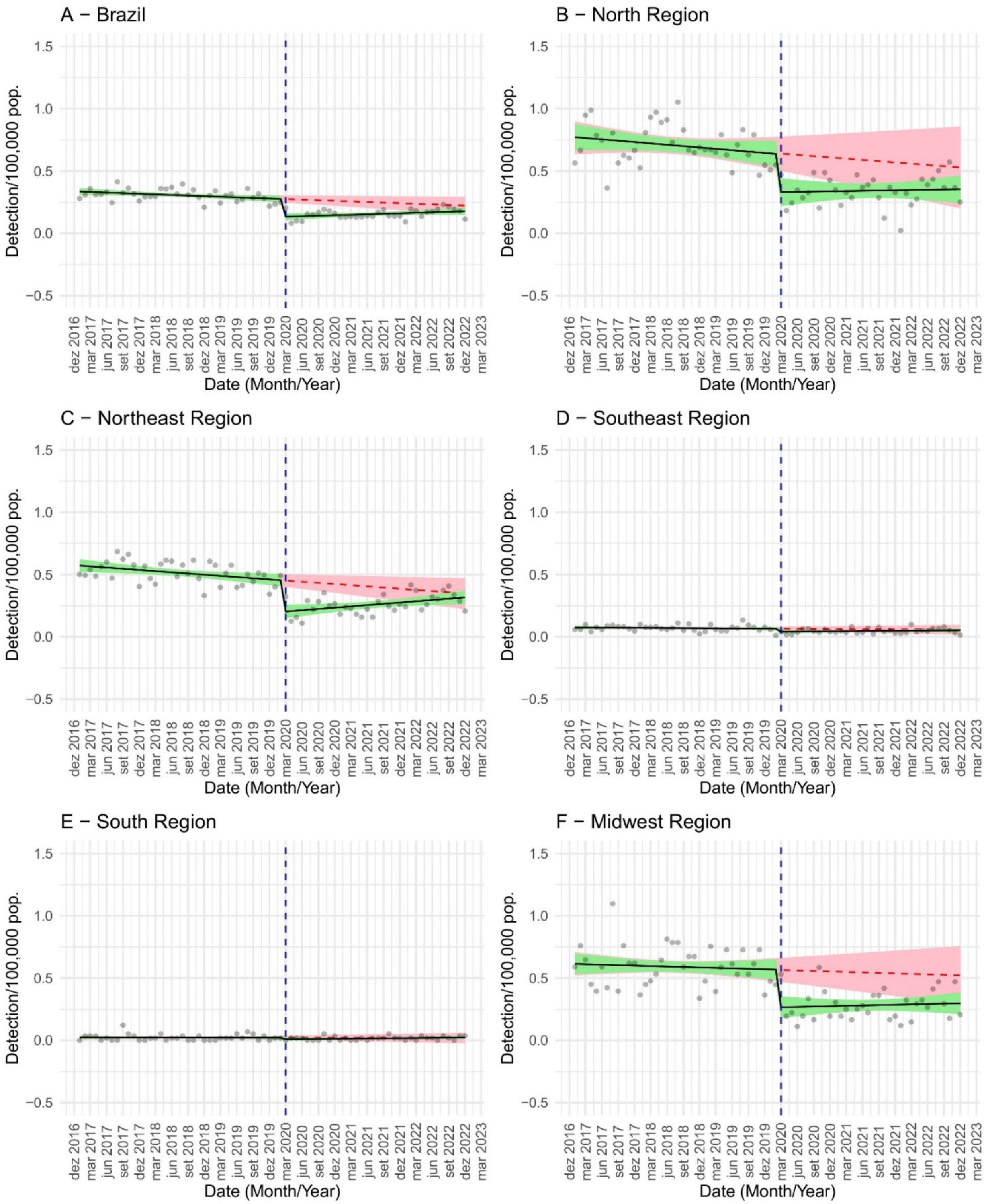

Fig. 3. Temporal pattern of the monthly detection rate of leprosy in individuals under 15 years of age before and after the COVID-19 pandemic in Brazil and its regions, 2017–2022. *Note*: Points represent the observed rates; the solid line represents modelled and adjusted detection rates without the seasonal component; the dashed line represents the counterfactual of expected cases; and the vertical dashed line represents the onset of the pandemic.

	Level change		Trend change		Durbin-Watson	R^2
	Impact	95% CI	Impact	95% CI		
Brazil	0.48***	0.40–0.57	1.01**	1.01–1.02	1.93	0.781
North Region	0.45***	0.31–0.67	1.01	0.99–1.02	2.00	0.505
Rondônia	1.82	0.60–1.05	1.04	0.99–1.02	2.01	−0.016
Acre	0.74	0.52–1.04	0.99*	0.97–0.98	1.95	0.164
Amazonas	1.21	0.51–2.89	1.01	0.97–1.06	1.97	−0.050
Roraima	1.11	0.81–1.50	1.01	0.99–1.02	1.98	−0.024
Pará	0.59**	0.42–0.83	0.99	0.97–1.00	1.98	0.542
Amapá	1.06	0.79–1.41	0.99	0.98–1.00	2.01	−0.019
Tocantins	0.26***	0.16–0.43	1.02	0.99–1.04	2.00	0.474
Northeast Region	0.44***	0.35–0.55	1.02***	1.01–1.03	1.93	0.705
Maranhão	0.47***	0.33–0.67	1.02*	1.01–1.04	1.97	0.414
Piauí	0.59*	0.35–0.98	1.03*	1.01–1.05	2.17	0.168
Ceará	0.50*	0.26–0.95	1.03	0.99–1.06	1.98	0.078
Rio Grande do Norte	0.99	0.47–2.08	0.99	0.96–1.03	1.91	0.023
Paraíba	0.81	0.41–1.60	0.98	0.94–1.01	1.92	−0.010
Pernambuco	0.38***	0.27–0.53	1.03**	1.01–1.04	2.05	0.578
Alagoas	1.36	1.02–1.80	0.98	0.95–1.01	1.97	−0.027
Sergipe	1.10	0.57–2.14	1.01	0.98–1.05	1.96	0.102
Bahia	0.31***	0.19–0.50	1.04**	1.01–1.06	1.98	0.490
Southeast Region	0.67*	0.45–0.99	1.02	1.00–1.03	1.90	0.290
Minas Gerais	0.41**	0.24–0.71	1.02	0.99–1.05	2.05	0.145
Espírito Santo	0.53	0.27–1.05	1.01	0.98–1.04	2.01	0.075
Rio de Janeiro	1.13	0.38–3.34	1.01	0.96–1.06	1.94	0.004
São Paulo	1.43	0.35–5.94	0.96	0.90–1.03	1.95	0.026
South Region	3.37	0.76–15.1	0.98	0.92–1.06	2.01	0.036
Paraná	2.62	0.63–10.9	0.95	0.89–1.01	1.98	0.012
Santa Catarina	0.94	0.37–2.44	0.95*	0.91–0.99	1.93	0.046
Rio Grande do Sul	1.17	0.45–2.88	1.03	0.99–1.07	1.93	0.072
Midwest Region	0.43***	0.33–0.57	1.01	0.99–1.02	1.99	0.670
Mato Grosso do Sul	1.43	0.71–2.88	0.98	0.95–1.02	2.02	0.038
Mato Grosso	0.41***	0.28–0.59	1.01	0.99–1.03	1.99	0.491
Goiás	0.70	0.37–1.35	1.00	0.97–1.03	2.06	0.030
Distrito Federal	1.28	0.71–2.32	1.01	0.98–1.03	2.01	−0.012

Table 2. Interrupted time series analysis of the monthly impact of the pandemic on the leprosy case detection rates in individuals under 15 years of age in Brazilian Federative Units, 2017–2022. 95% CI: 95% confidence interval; R^2: adjusted R-squared; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

and socioeconomic disparities in the country[28]. Regions with better access to healthcare services, adequate infrastructure, and available resources may have been less affected by the interruption of health services following the onset of the pandemic, resulting in a smaller decrease in leprosy detection in these regions than in less developed regions.

Several aspects related to the late detection of leprosy cases may have been exacerbated by the pandemic. Among structural factors, distance from healthcare services, the organization of health services, the number of leprosy cases, and logistics for leprosy actions influence the late detection of new cases. Additionally, passive case detection, the presence of a limited number of health centres, the presence of a scarce number of leprosy specialists, limited knowledge among health teams, a lack of local leadership, high turnover among healthcare professionals, low commitment from healthcare professionals, few community activities for leprosy control, and prejudice among healthcare professionals have been identified as factors contributing to the late detection of leprosy. All these factors can lead to incorrect diagnoses and further delay leprosy detection[29].

Additionally, the reduction in the detection of new cases may have been influenced by changes in population behaviours following the onset of the pandemic[30,31]. Social distancing measures and mobility restrictions led people to delay or avoid seeking medical care[32]. This could have resulted in undiagnosed or late-stage leprosy cases, which may lead to additional complications for patients and complicate disease control efforts[33].

Despite the decrease in new leprosy cases detected following the onset of the COVID-19 pandemic, a linkage study conducted by the Brazilian Ministry of Health revealed a heterogeneous distribution of coinfection based on the federative unit of residence. In this context, Goiás, Amazonas, Santa Catarina, Minas Gerais, and the Federal District were the five states with the highest incidence rates of COVID-19 among people with leprosy.

Notably, treatment for people with leprosy continued, with those at greater vulnerability to COVID-19 receiving medications at home or through a caregiver[34].

Nevertheless, importantly, the reduction in leprosy detection after the onset of the pandemic may have significant long-term consequences, especially concerning the active transmission chain[35]. Leprosy is an infectious disease that requires early intervention to prevent severe complications. This is particularly relevant given the resumption of case identification in individuals under 15 years of age, who are considered active transmitters of the disease[6]. The results also indicate that, on one hand, there is a greater capacity of the health system to retain the pediatric population. On the other hand, the underdiagnosis of cases that occurred after the onset of the pandemic may result in an even greater leprosy burden in the future.

This concern was reinforced only towards the end of 2022, as the diagnostic patterns that were in place before the pandemic resumed in some regions. Additionally, data from Brazil indicate a rise in the detection of patients with G2D in the country[6]. Thus, cases that should have been diagnosed have not yet been detected, with an expected increase compared to the prepandemic standard. For example, the stationary detection of leprosy cases in the Midwest Region following the onset of the pandemic plus the lack of resumption of diagnoses indicates that Brazil faces regional challenges in addressing leprosy. This finding may be explained by factors such as the increase in patients with G2D and the decrease in contact evaluations over the past 10 years[6,8].

The resumption of leprosy detection after the onset of the pandemic is an important result of this study. This recovery may be related to economic factors; for example, the Southeast Region, which showed the best recovery in case detection, is the most industrialized region in the country. These findings reinforce previous data showing the greater impact of COVID-19 on leprosy detection in less economically developed regions[36].

Therefore, the results of this analysis highlight the need for urgent measures to mitigate the impacts of the COVID-19 pandemic on leprosy detection in Brazil. This includes strengthening health systems, promoting awareness about leprosy, and implementing early screening and diagnostic strategies to resume case detection. These measures are essential to prevent an increase in active disease transmission and new patients with visible physical disabilities, ensuring effective disease control and protecting public health.

In this regard, an important recently implemented measure, the Healthy Brazil Program, aims to work with several ministries to eliminate a set of socially determined diseases as public health problems by addressing hunger and poverty, reducing inequalities, expanding infrastructure, and improving basic sanitation, among other actions. Thus, the implementation of this program is expected to enhance leprosy early diagnosis, ensuring that cases missed since the pandemic receive appropriate treatment while also preventing physical disabilities[11].

One of the limitations of this study was the use of secondary data, of routine notification system, during the COVID-19 pandemic. We believed that underreporting might be subject to be increased due to the efforts to deal the public health emergency. Moreover, this analysis are limited to 2022, which was the time available during the time of analysis. Currently, this trend may present a different aspect and, thus, interpretations should be taken cautiously. Additional indicators as grade 2 disability, prevalence, and multibacillary were not evaluated and the impact of the pandemic in other operational aspects could not be taken into account.

In summary, the COVID-19 pandemic has significantly affected leprosy detection in Brazil, leading to an immediate impact of 0.55 reduction in overall case detection and a 0.48 reduction among individuals under 15 years of age. Although a gradual, modest monthly increase in detection was observed following the onset of the pandemic. This study is novel in its use of interrupted time series analysis to estimate the immediate and long-term effects of the pandemic on a neglected tropical disease at both national and subnational levels, particularly highlighting the vulnerability of younger populations and the need for region-specific interventions.

These findings provide evidence for health authorities, emphasizing the importance of strengthening programs to combat neglected tropical diseases like leprosy, especially during public health crises. Finally, strengthening surveillance systems and allocating funds to improve early diagnosis, treatment, disability prevention, and efforts to reduce stigma and discrimination are essential to mitigate an even longer impact of the pandemic on leprosy.

Data availability

The data used are public and available from the Informatics Department of the SUS/Brazilian Ministry Health (DATASUS) and the Brazilian Institute of Geography and Statistics (IBGE). The data can be freely accessed at https://datasus.saude.gov.br/.

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Author contributions
All the authors contributed to the study conception and design. GJBS had access to raw data, and DSL, PPLB, MCNR and SASN accessed and verified the data and performed material preparation, data collection and analysis. The first draft of the manuscript was written by GJBS, DSL, and PPLB, and all the authors commented on previous versions of the manuscript. MCNR, SASN, JGB, FCFL, CHA, MLDP, AMC, and CMG contributed to

reviewing and editing the final version. All the authors read and approved the final manuscript and were responsible for the decision to submit the manuscript. GJBS had the final responsibility to submit the manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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