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Vaccination against poliomyelitis in Brazil from 2011 to 2021: successes, setbacks, and challenges ahead

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Abstract *The drop in childhood vaccination coverage (VC), including poliomyelitis, has become a health concern. The objective was to analyze the temporal trend of coverage of the three doses of the polio vaccine in the first 12 months of life between 2011 and 2021, in addition to mapping vaccination coverage in Brazil, including the COVID-19 pandemic period. An ecological study was carried out using interrupted time series (STI) techniques and spatial analysis, with data from the National Immunization Program Information System. The VC trend was adjusted by the Newey-West variance estimator according to the federated units and the Brazilian Deprivation Index. The VC distribution was estimated by Bayesian models and the spatial clusters by the global and local Moran index, identifying areas of lower coverage in the health regions. There was a reduction in the VC over the period in all regions, being more pronounced in the North and Northeast regions and during the Covid-19 pandemic. The biggest drops were identified in states and health regions with greater social vulnerability after 2019. The drop in VC shows that the risk of reintroduction of the wild virus is imminent and the challenges need to be faced with the strengthening of the Brazilian Health System (SUS).*

Key words *Vaccination coverage, Immunization, Spatial analysis, Ecological studies, Poliomyelitis, COVID-19*

Introduction

Vaccines are one of the most outstanding achievements in public health, with a substantial impact on child survival, control, and eradication of diseases worldwide[1]. In Brazil, the National Immunization Program (PNI) started to coordinate immunization activities in 1975, expanding the distribution and regulation of the use of immunobiologicals and becoming a successful, internationally recognized program. Considerable advances have been made over the years in controlling and eliminating severe diseases circulating in the national territory. Some of the PNI's remarkable achievements are the disruption of wild poliovirus transmission in Brazil with an oral vaccine composed of attenuated poliovirus 1, 2, and 3 and the organization of national vaccination days with the oral polio vaccine; that is, mass vaccination of children under five twice a year, resulting in a 90% reduction in cases from 1980 to 1981.

In the Americas, the last confirmed case of poliomyelitis caused by wild poliovirus occurred in 1991. Brazil received certification for the elimination of poliomyelitis in 1994. However, the wild virus still circulates in Asian countries, persisting between Afghanistan and Pakistan, with a risk of reintroduction in Brazil, particularly in the context of a declining population's immunity due to reduced vaccination coverage[2-5]. Vaccination coverage (VC) is a strategic indicator of the PNI, as it reveals the protection of the population at the community level and allows assessing herd immunity. The lower percentages of people covered by immunobiologicals reveal the existence of unprotected groups, in which the viral circulation can extend and affect immunocompromised individuals under one year of age, with a massive impact on morbimortality.

Several studies have shown a drop in childhood vaccination coverage, including polio, particularly in the last decade in Brazil. Other challenges also emerged with the COVID-19 pandemic and significantly affected routine immunization worldwide, with a declining recording, delayed vaccination[6-8], and vaccine hesitancy[9].

Thus, estimating the VC over time is crucial to assess the proposed goals and challenges for the country. In this context, this study aims to analyze the temporal trend and spatial distribution of coverage of the three doses of the polio vaccine in the first 12 months of life in Brazil in the last decade, emphasizing the COVID-19 pandemic years.

Methods

An ecologically designed study was conducted on vaccination coverage for poliomyelitis using spatial and temporal analysis techniques. The temporal approach adopted the interrupted time series (ITS) technique to analyze the trend from 2011 to 2021 and the impact of the COVID-19 pandemic that started in 2020 by federation unit and quintile of the Brazilian Deprivation Index (BDI). The spatial analysis technique was performed to identify differences in the distribution of vaccination coverage by PNI target range (≥ 95%; 85 to 94; 70 to 84 and < 70%) in the 450 Brazilian health regions for 2011, 2015, 2019, and 2021.

The vaccination coverage data recorded by the National Immunization Program Information System (SI-PNI) were retrieved from the Department of Informatics of the SUS (DATASUS) website on October 20, 2022. The target population data were retrieved from the Live Births Information System (SINASC) on the same website. The BDI was obtained from the Health Data and Knowledge Integration Center (CIDACS) website.

Poliomyelitis vaccination coverage comprises the complete vaccination schedule for the first year of life: the three doses (at 2, 4, and 6 months). Vaccination coverage was calculated by dividing the doses applied by the target population (live births), multiplied by 100 for each year and area of analysis[10].

The Brazilian Deprivation Index (BDI) is an indicator based on the 2010 Demographic Census, which classifies municipalities into quintiles of deprivation, with quintile 1 being the lowest and quintile 5 being the most deprived. The composition of the BDI considers the following indicators: the percentage of households with per capita income below half minimum wage; the percentage of illiterate people aged seven or over; and the percentage of households with inadequate access to basic sanitation and without running water, garbage collection, toilet, and bathroom at home[11].

The interrupted time series (ITS) method is a quasi-experimental approach to assess the effects of interventions on longitudinal data[12]. It allows estimating level and trend changes when the outcome variable is sorted sequentially as time series and when multiple observations are captured in the pre-intervention and post-intervention periods[13]. This design has robust internal validity, even in the absence of a comparison group,

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mainly because of its control over the regression effects to the mean[12].

The models for each federation unit and by BDI quintiles were fitted using the Stata/MP 16.1 software, using a single-group lag design of a Newey-West[14] variance estimator, which produces consistent estimates in the presence of autocorrelation, besides possible heteroscedasticity[15]. The coefficients are based on ordinary least squares regression (OLS) and appear as follows:

$y = \beta_0 + \beta_1$*time + β_2*level + β_3* (time*intervention); where:

- β_1= utilization trend curve slope before the intervention (between January 2011 and December 2019).

- β_2= vaccine coverage level change when the COVID-19 pandemic started (2020) (comparison with counterfactual).

- β_3= coverage trend curve slope after the first year of the pandemic (December 2020 to December 2021).

Overall trend – the difference in trend from the period before the intervention versus the trend after the intervention.

Serial autocorrelation and heteroscedasticity were measured by the Cumby-Huizinga test[16]. The significance level was set at 5% for all analyses. A spatial analysis of poliomyelitis VC was performed in the 450 Brazilian Health Regions in 2011, 2015, 2019, and 2021, considering ranges of > 95% (adequate), 85% to 94%, 70% to 84%, and < 70%, by PNI target.

The Health Region conceptualized by the Ministry of Health is a continuous geographic space resulting from the union of neighboring municipalities in cultural, economic, and social identities, considering the communication networks and shared transport infrastructure created to integrate the organization, planning, and implementation of health actions[17].

In the spatial analysis, the smoothed estimators for the vaccination coverage rates in the study years were obtained by Bayesian models with the Poisson distribution. The models included a random effect with autoregressive conditional normal structure, which allowed higher correlations between the close areas in the space[18]. The Markov Chain Monte Carlo method (MCMC) implemented in the GeoBUGS module of the OpenBUGS computer program (Medical Research Council, Biostatistics Unit, Cambridge, United Kingdom) was used to estimate the model parameters.

The global Moran index estimated the magnitude of the spatial autocorrelation between the regions, in which values close to zero indicate that the observed VC rates are randomly distributed in the geographic space without spatial clusters. The Local Indicator of Spatial Association (LISA) allowed identifying significant spatial association patterns, representing a decomposed global index. LISA classified the Health Regions by the significance levels of the values of their local vaccination coverage indices, "high-high", "low-low", "high/low", and "low/high". Regions classified as "high-high" and "low-low" have high and low VC rates, respectively, and neighbors with similar values. Regions classified as "high-low" and "low-high" indicate a negative association; that is, the location has neighbors with different values. The other regions are classified as "non-significant"; that is, without a clear spatial trend.

According to Article 1 of Resolution N° 510/2016 of the National Research Ethics Committee, the study did not require approval from the Research Ethics Committee because it exclusively used secondary, anonymized, and publicly accessible data.

Results

In 2011, almost half of the federation units had vaccine coverage for poliomyelitis estimated at 100% or more, while this event was not observed in any state in 2021. The analyzed period evidenced a drop in VC and a statistically significant global difference for all federation units (Figure 1 to 5; Suppl. Table 1, available at: https://doi.org/10.48331/scielodata.O4CS0B). The federation unit with the highest decline was Roraima (-14.84; 95% confidence interval 95%CI: -20.45; -9.23), and the lowest, Tocantins (-4.34; 95%CI: -4.38; -4.30). In general, the states of the North (Amapá, Roraima, Acre, and Rondônia) and Northeast (Ceará, Paraíba, and Pernambuco) recorded the most significant drops and overall differences in VC during the study period (Suppl. Table 1, available at: https://doi.org/10.48331/scielodata.O4CS0B).

The VC annual mean trends before and after the onset of the pandemic are heterogeneous for municipalities of quintile 1 (lowest deprivation) compared to those in quintile 5 (highest deprivation) of the BDI (Figure 4; Suppl. Table 2, available at: https://doi.org/10.48331/scielodata.O4CS0B). In quintile 1, polio VC was estimated at 107.14% at baseline with a downward annual trend of

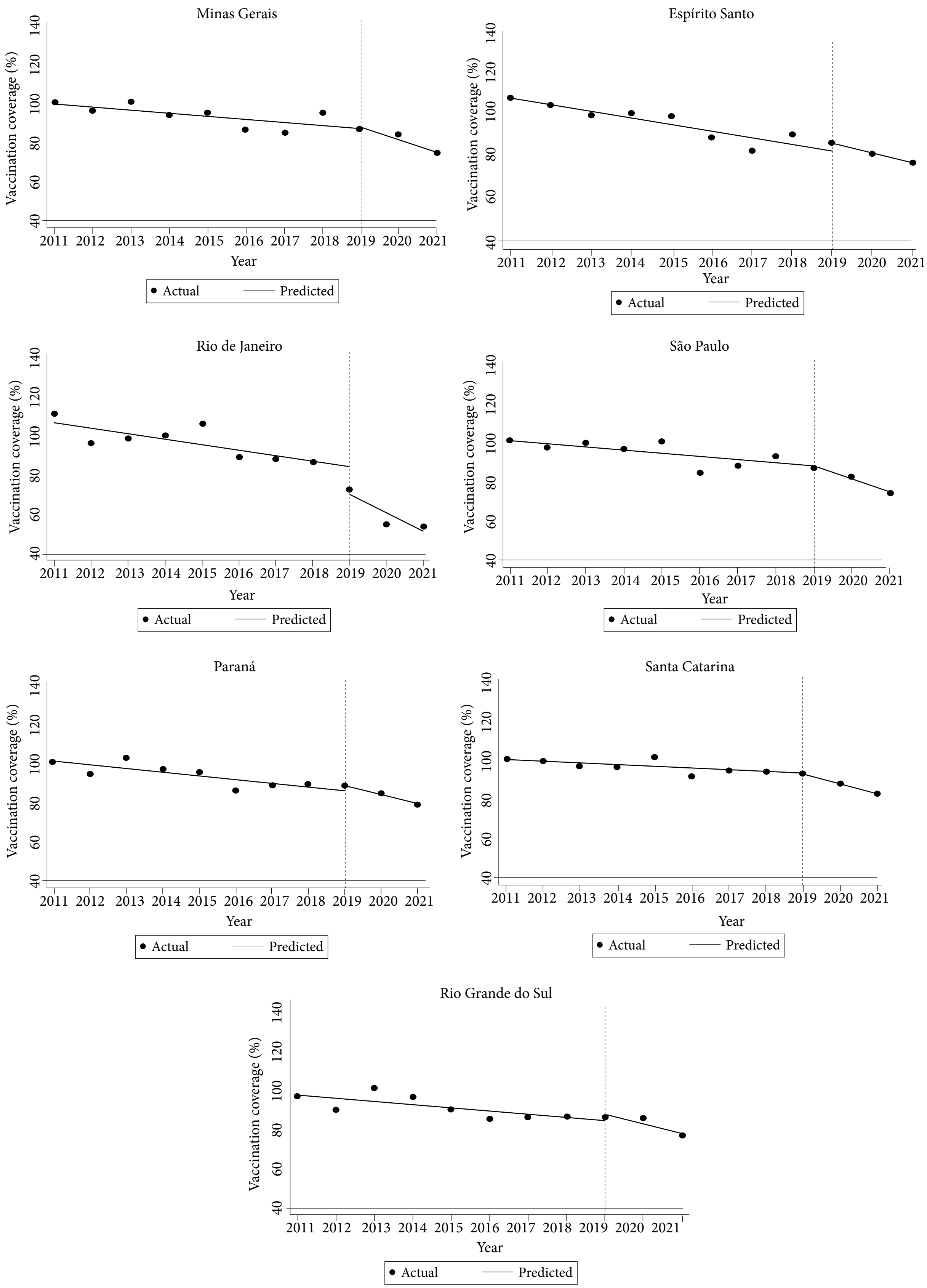

Figure 1. Trends in polio vaccine coverage in the federation units of the Southeast and South regions, Brazil, 2011-2021.

Source: Authors, based on SI-PNI data, Ministry of Health, Brazil.

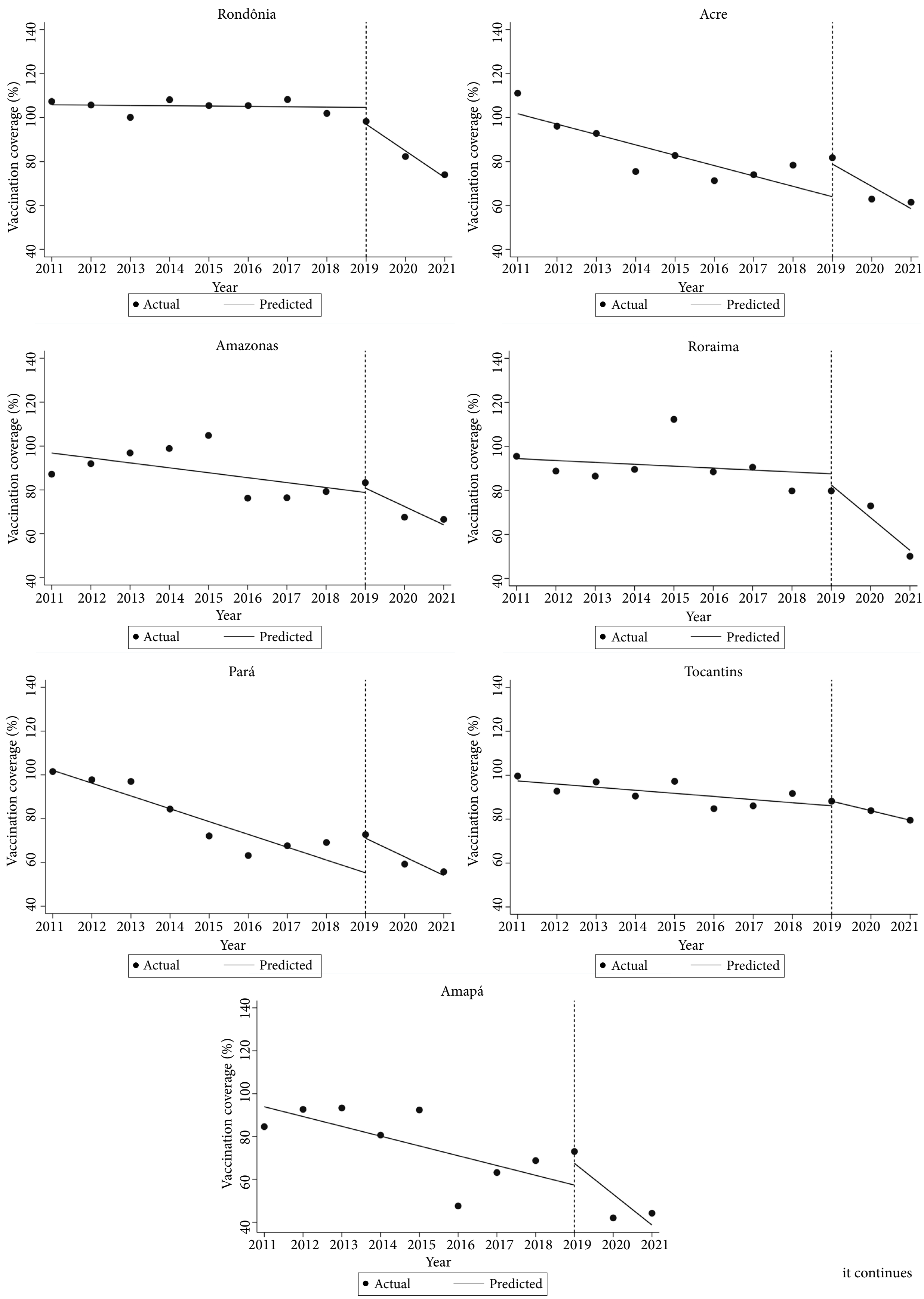

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Figure 2. Trends in polio vaccine coverage in the federation units of the North and Midwest region, Brazil, 2011-2021.

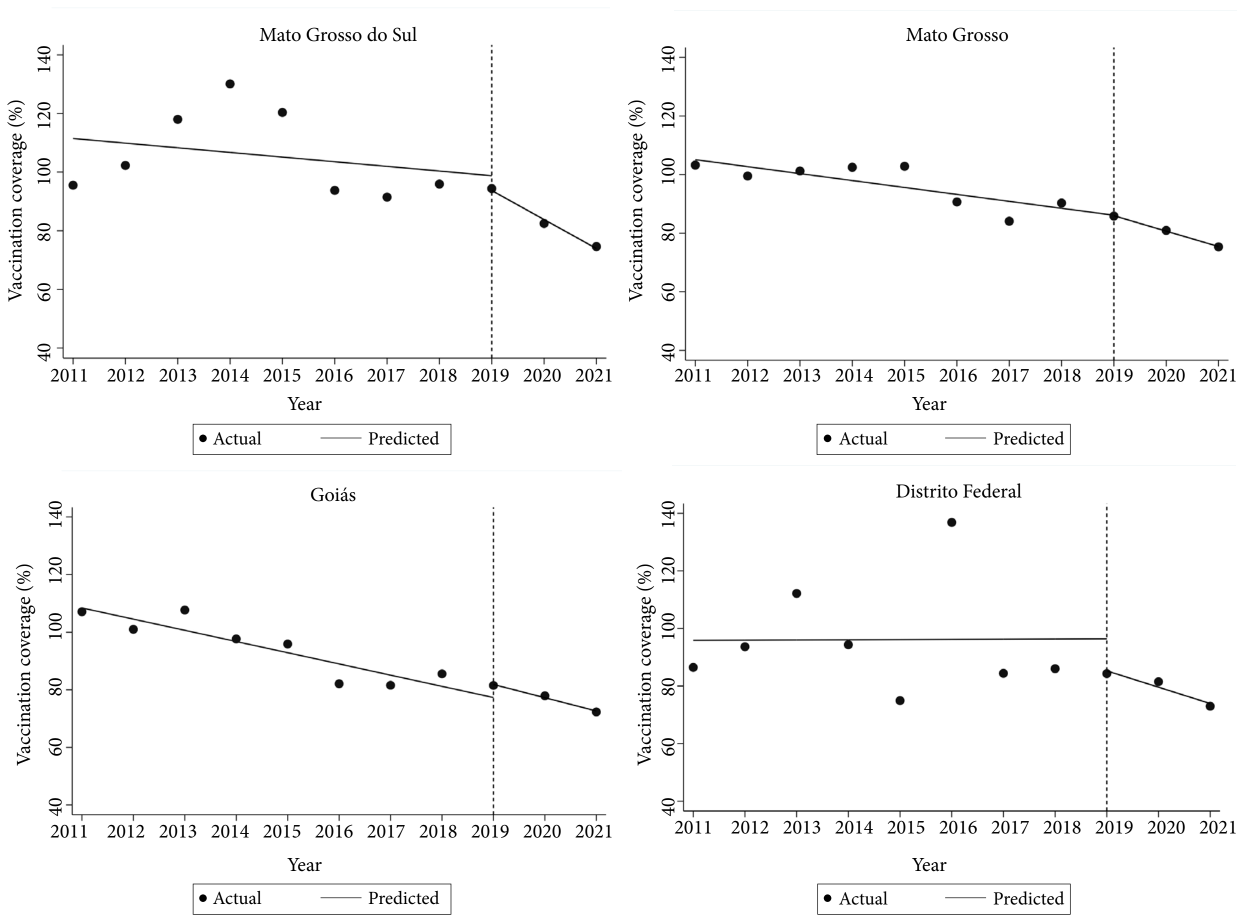

Figure 2. Trends in polio vaccine coverage in the federation units of the North and Midwest region, Brazil, 2011-2021.

Source: Authors, based on SI-PNI data, Ministry of Health, Brazil.

-1.96% (95%CI: -3.10; -0.82). There was no change in the level (impact of the pandemic in the first year), but the slope (trend after the onset of the pandemic) declined annually by -2.54% (95%CI: -4.97; -0.11) after the onset of the pandemic. The overall difference in the COVID-19 impact on the polio VC in the first quintile of the BDI was -4.50% (95%CI: -6.74; -2.26). In quintile 5, the polio VC was estimated at 105.27% at the beginning of the period, with a downward annual trend of -2.02 (95%CI -4.00; -0.04). There was no change in the level (immediate impact of the pandemic in the first year), but the slope changed, producing an annual fall in the trend of -5.52 (95%CI: -8.37; -2.66) after the onset of the pandemic. The global difference in the impact of COVID-19 on the polio VC in the fifth quintile of the BDI was estimated at -7.54% (95%CI: -9.09; -5.98), showing a more significant drop in VC than that observed in less deprived municipalities.

The maps with the vaccine coverage ranges depict a consistent decline in the percentages of the three doses of the polio vaccine in the first year of life in the health regions of the country (Figure 5). Health regions that reached vaccination coverage targets (≥ 95%) were progressively disappearing from the maps in the study years. In comparison, regions with coverage below 70% were predominant in the North and Northeast in 2019 and 2021. We also observed that clusters of regions with low coverage are concentrated in the North (Figure 5).

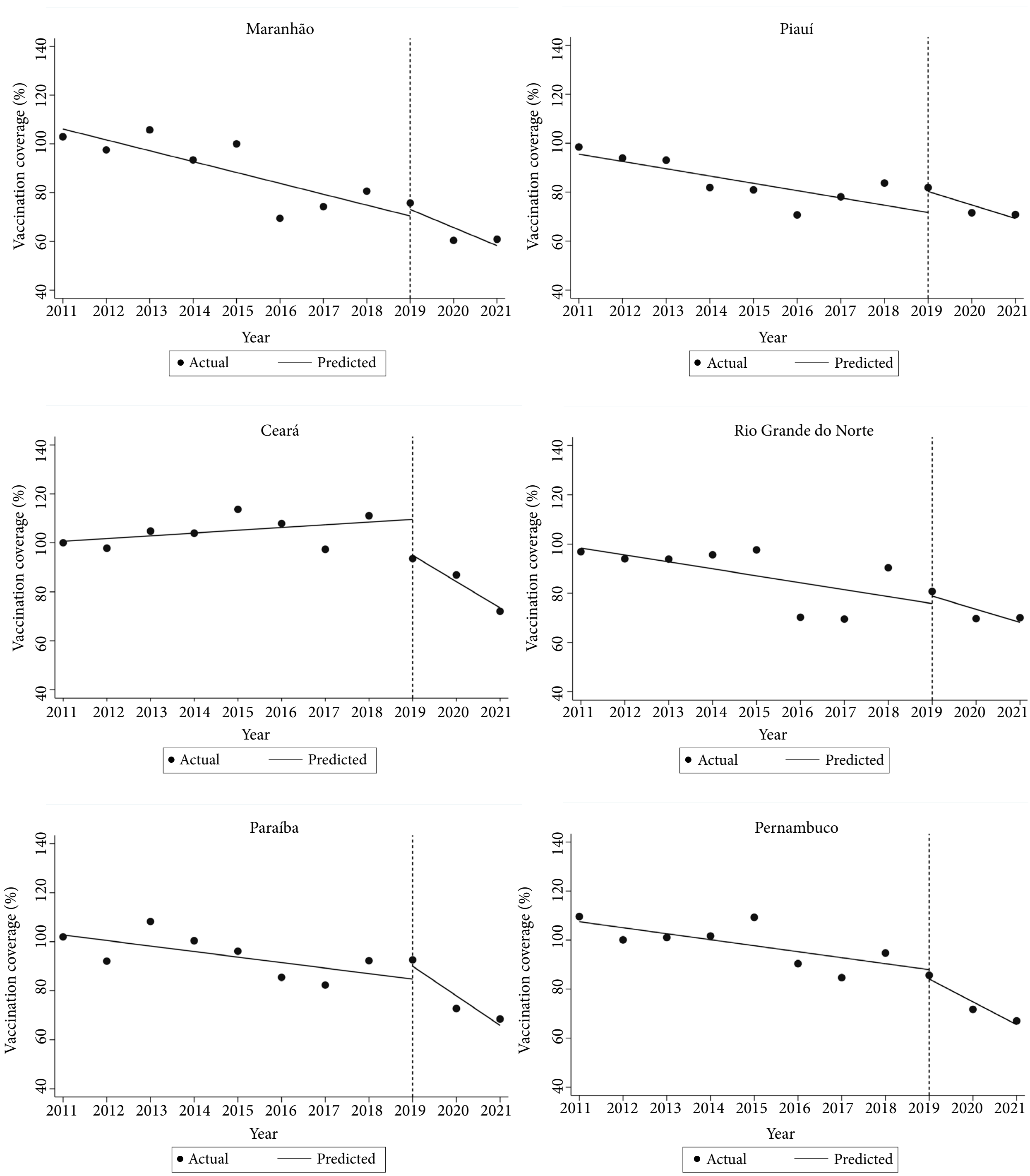

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Figure 3. Trends in polio vaccine coverage in the federation units of the Northeast region, Brazil, 2011-2021.

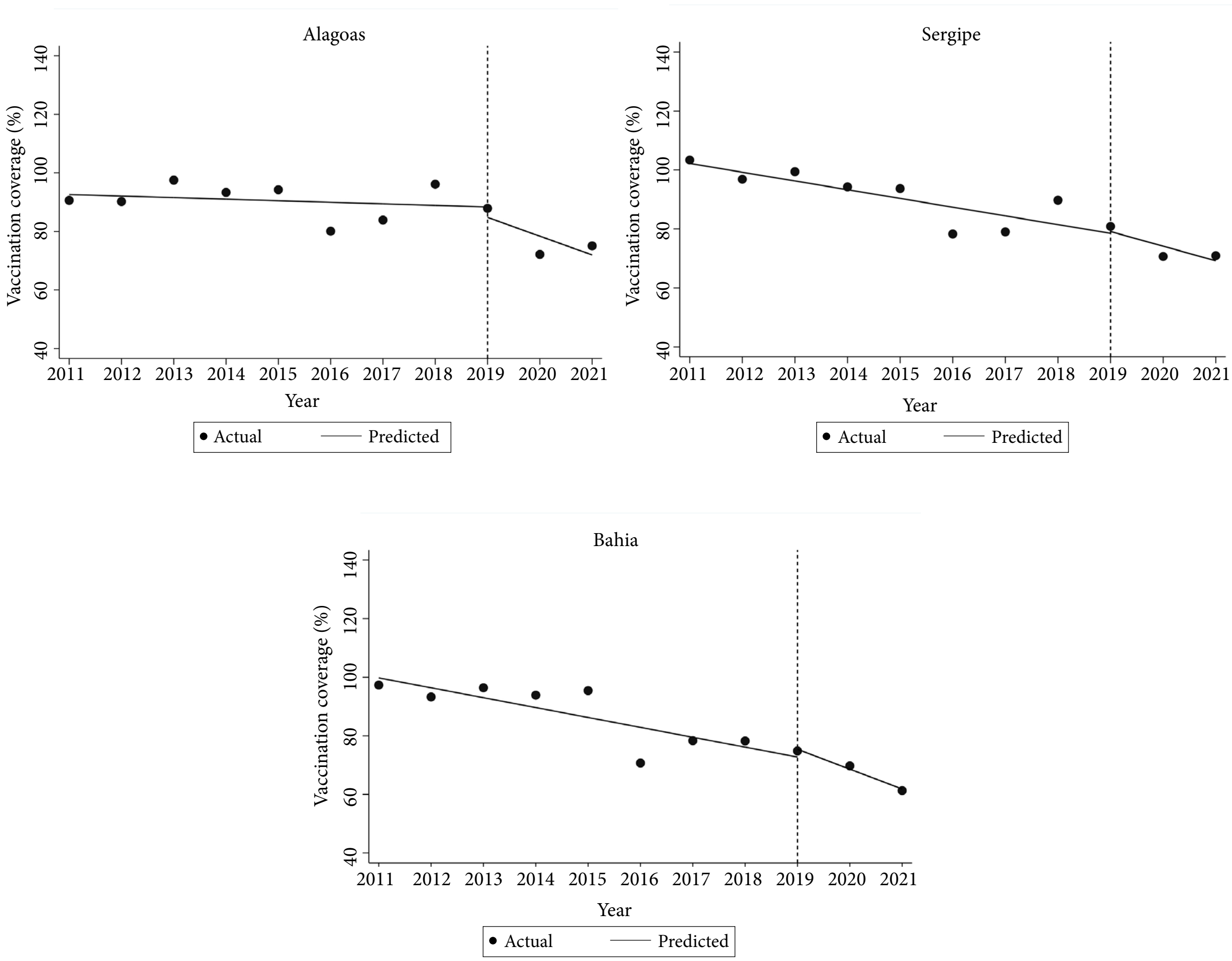

Figure 3. Trends in polio vaccine coverage in the federation units of the Northeast region, Brazil, 2011-2021.

Source: Authors, based on SI-PNI data, Ministry of Health, Brazil.

Discussion

A consistent decrease in polio VC in the first year of life (three doses) is observed in all regions of the country, albeit heterogeneous in the study period, more significant in more deprived municipalities. The North and Northeast stand out for the sharpest declines, with a more evident reduction in the trend from 2020, the COVID-19 pandemic year. In the same vein, the maps reveal a progressive loss of adequate percentages of 95% of polio VC in the country. The 95% target observed in 2011 in most health regions is practically nonexistent in 2021. The results draw attention to the low coverage clusters in the North and Northeast, with the highest concentration of socially vulnerable populations.

Estimates indicate that Latin American countries, including Brazil, have very low and heterogeneous vaccine coverage against polio and other vaccines, leaving large populations at risk of outbreaks[19-22]. A study conducted with data from 2006 to 2016 indicated a downward trend in polio vaccination coverage, with an annual reduction of 1.3% in the analyzed period and heterogeneously in the country[20].

The drop in vaccination coverage has been attributed to several factors, including the underfunding of the Brazilian Unified Health System (SUS)[23], problems in service management, orga-

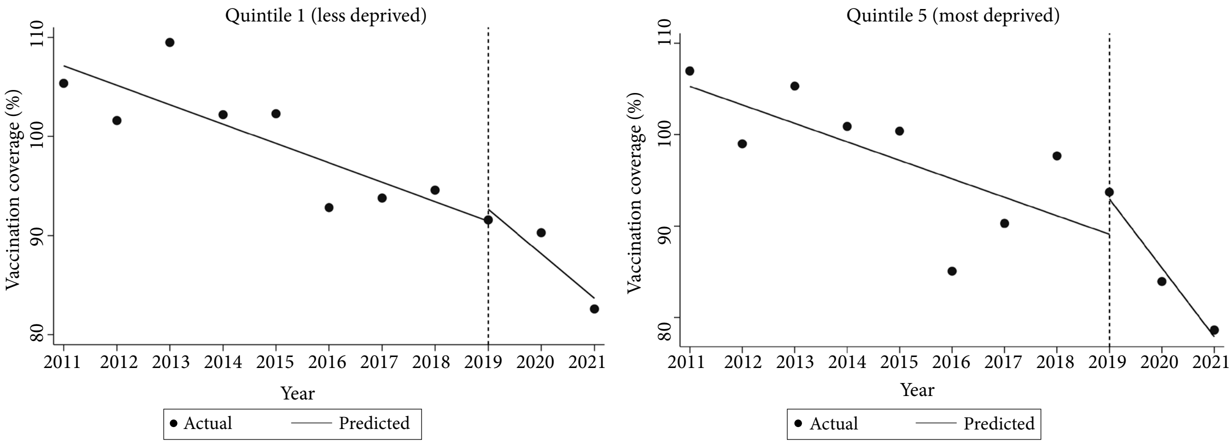

Figure 4. Trends in polio vaccination coverage of municipalities placed in the first and fifth quintiles of the Brazilian Deprivation Index, Brazil, 2011-2021.

Source: Authors, based on SI-PNI data, Ministry of Health, Brazil.

nization of vaccination rooms, and health communication, besides the increase in vaccines in the calendar, resulting in greater program complexity, from management to administration[21]. Moreover, they contribute to VC decline, the information system change from applied dose data to individual data, the lack of knowledge of the importance of vaccination, the strengthening of anti-vaccine movements, and the dissemination of fake news, which reinforce vaccination hesitancy[9]. The main issues involved in vaccine hesitancy are the insecurity regarding its efficacy/quality and the political and organizational dissonances between government sectors, health entities, and supranational bodies.

Another factor contributing to the declining vaccination coverage is socioeconomic inequalities[24,25]. In this sense, the findings of this study corroborate a more significant drop in VC in the states of the North and Northeast and the more deprived municipalities. Arroyo et al. (2020)[20] recorded a faster decline in coverage in these regions, mainly in the states of Pará, Maranhão, and Bahia. Although several studies point to lower vaccination coverage among more socially vulnerable segments of the population[24,25], this association may be inverse depending on the health system's characteristics[26,27]. In countries with health systems with universal and free vaccine availability, such as Brazil, vaccination coverage can be considered an indicator of access to the PNI[26]. Domingues et al. (2020)[9] consider that the good performance observed between 2000 and 2015 expressed the equal access promoted by the SUS[23]. However, socioeconomic determinants also affect vaccination due to the complex relationship with trust in the immunization program, services, and health professionals and complacency related to the low perception of the risk of vaccine-preventable diseases[28].

Besides decreasing vaccine coverage, the COVID-19 pandemic brought additional challenges concerning lower coverage and increasing social inequalities, affecting the most vulnerable population[29,30]. In 2021, the deterioration caused by the COVID-19 pandemic had already been observed, estimating that only 80% of children received the three doses of the polio vaccine and 25 million children under one year of age had not received the primary vaccination schedule, the highest number since 2009[31].

International studies also reported that the pandemic affected access to routine vaccination services[32,33]. The high demand for professionals on the frontline generated elective care restrictions, interrupted vaccination room routines,

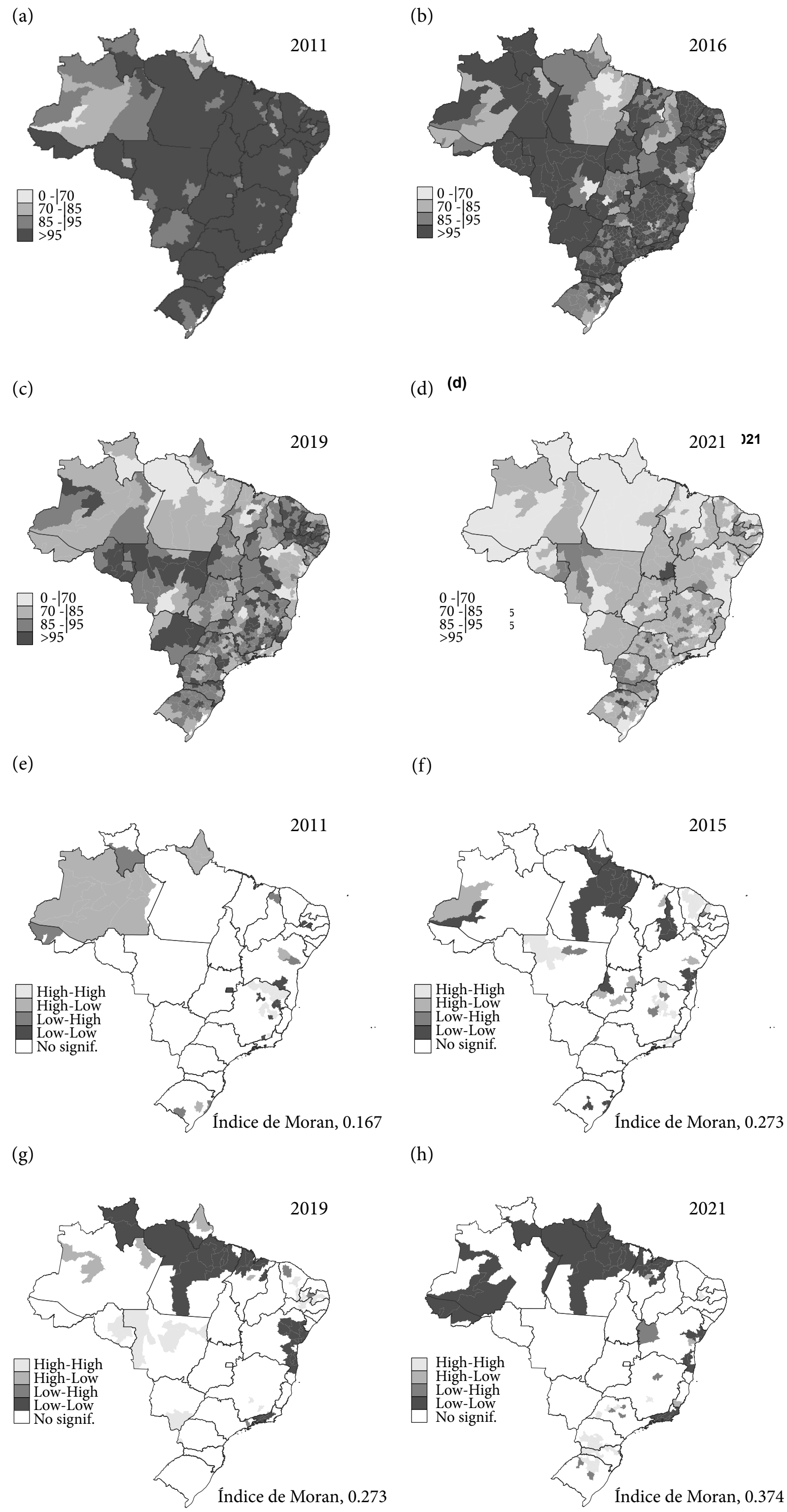

Figure 5. a_d) Maps with ranges of polio vaccine coverage in health regions according to Bayesian models. e_f) Patterns of spatial association in vaccine coverage clusters (low-low, high-high, low-high and high-low) using the global and local Moran Index of Spatial Association. Brazil 2011 to 2021.

Source: Authors, based on data from SI-PNI, DATASUS, Ministry of Health and IBGE, Brazil.

leaving many children unvaccinated[8,34]. In Brazil, studies have described this marked drop in children from poorer households[8,35,36], besides the spatial heterogeneity of these indicators between Brazilian municipalities and regions[20,21].

Low vaccination coverage and the existing inequality are troubling due to the risk of re-emergence and lack of control of vaccine-preventable diseases. Moreover, at the 14th Meeting of the Regional Poliomyelitis Eradication Certification Commission for the Americas in 2022, the region was considered at very high risk for the reintroduction of poliomyelitis. This risk analysis considers vaccine coverage, epidemiological surveillance of acute flaccid paralysis, poliovirus laboratory containment situation, health determinants, and outbreak preparedness[37].

International strategies have been launched to reverse the situation. The 2030 Immunization Agenda aims for "a world where everyone, everywhere, at all ages, benefits from vaccines", consolidating gains made in decades by immunization programs and recovering from the disruptions caused by the pandemic[31]. It is crucial to revisit vaccination strategies, focusing on equity and the most vulnerable populations[38].

In this sense, in November 2022, the Brazilian Ministry of Health launched the National Plan for the Response to the Detection of Poliovirus and Poliomyelitis Outbreak to establish guidelines for timely responses to the detection or an outbreak caused by wild poliovirus or vaccine-derived poliovirus by strengthening the national and operational capacity of states and municipalities[39].

However, several challenges have been pointed out to keep the eradication of poliovirus in Brazil, such as reducing dropout rates, increasing VC homogeneity, and consolidating the surveillance of flaccid paralysis and laboratory and genomic surveillance of poliomyelitis cases caused by vaccine-derived viruses[40]. Investing in the PHC network, training of teams, and a better structure of vaccine rooms is essential as it can resume the goal of adequate vaccine coverage for poliomyelitis and other vaccines in the country, as in times past and border partnerships. The importance of community health workers in rescuing vaccine abandonment cases in the territories is also highlighted, along with the relevance of improving and updating health communication strategies to increase trust in vaccines and counter anti-vaccination movements.

One of the study's main limitations is secondary data use, with information only sometimes complete and accurate. The unit of analysis was the VC already calculated by the PNI in years, which generates a time series with few points in time and may result in low statistical power and, thus, lower precision of estimates and wider confidence intervals. However, no predictions were made, only a description of changes in VC in the period, and the results must be interpreted cautiously. Another element is the change in data collection, which, as of 2013, began to be recorded in real-time. The inaccurate information and lack of data from the private health services and records on days of vaccination campaigns are also noteworthy.

Notwithstanding, these data are from an official population-based information system on vaccination that covers the entire national territory. Population estimates were obtained from the 2010 Census database of the Brazilian Institute of Geography and Statistics (IBGE) and may not reflect the actual composition of the age group studied. Vaccination coverage exceeding 100% may indicate inaccuracies in the estimates concerning the target population and information about the number of doses applied[29].

Conclusion

Over the years, particularly after the onset of the COVID-19 pandemic, federation units and Brazilian health regions showed differences between the declining coverage of a vital vaccine against poliomyelitis in the first 12 months of a child's life. The most significant drops were identified in federation units and health regions with greater social vulnerability after 2019. In the globalized context, the decrease in polio vaccine coverage in Brazil in the last decade shows that the risk of reintroduction and circulation of the wild virus is imminent, the setback is real, and the challenges must be addressed by strengthening the SUS and the known excellence of the PNI.

Collaborations

MR Donalisio, AC Boing and APS Sato participated in the study design, discussion of results and writing of the text. A Matijasevich, EZ Martinez, MO Xavier, RLF Almeida and RS Moreira participated in the study design, collection, curation, analysis and revision of the manuscript. RCS Queiroz contributed with the study design and discussion of the results. All authors contributed to the discussion of the results, critical review of the text and approval of the version to be published.

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