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YELLOW FEVER VACCINATION COVERAGE IN BRAZIL BETWEEN 2019 AND 2022: A DESCRIPTIVE ECOLOGICAL STUDY

COBERTURA VACINAL CONTRA FEBRE AMARELA NO BRASIL ENTRE 2019 E 2022: ESTUDO DESCRITIVO DE ABORDAGEM ECOLÓGICA

COBERTURA DE VACUNACIÓN CONTRA LA FIEBRE AMARILLA EN BRASIL ENTRE 2019 Y 2022: ESTUDIO DESCRIPTIVO CON ENFOQUE ECOLÓGICO

Daniele Vieira da Silva Blamires[1], Aldenora Maria Ximenes Rodrigues[2]

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ABSTRACT
Yellow fever remains a significant public health concern in Brazil, with vaccination serving as the primary strategy for disease prevention and control. This study analyzed yellow fever vaccination coverage across the Brazilian macro-regions between 2019 and 2022, considering the context of the COVID-19 pandemic and its potential impact on immunization services. This was an ecological observational study based on secondary data obtained from the Brazilian National Immunization Program Information System (SI-PNI/DATASUS) and the Brazilian Institute of Geography and Statistics (IBGE). Vaccination coverage was stratified by macro-region and year and compared with the 95% target established by the Brazilian Ministry of Health. None of the macro-regions achieved the recommended target during the study period. National vaccination coverage declined progressively from 73.44% in 2019 to 61.52% in 2021, followed by a partial recovery to 67.93% in 2022. Statistically significant differences were observed among the years evaluated. The North region presented the lowest coverage rates and the greatest reductions, whereas the South region maintained the highest vaccination coverage. Despite the improvement observed in 2022, vaccination coverage remained below the recommended level, highlighting persistent regional inequalities and the need for targeted strategies to expand immunization and reduce epidemiological vulnerabilities.

KEYWORDS: Yellow Fever. Vaccination. Immunization. COVID-19. Brazil.

RESUMO
A febre amarela permanece como importante problema de saúde pública no Brasil, sendo a vacinação a principal estratégia de prevenção e controle da doença. Este estudo analisou a cobertura vacinal contra febre amarela nas macrorregiões brasileiras entre 2019 e 2022, considerando o contexto da pandemia de COVID-19 e seus possíveis impactos sobre os serviços de imunização. Trata-se de um estudo observacional ecológico realizado com dados secundários provenientes do Sistema de Informações do Programa Nacional de Imunizações (SI-PNI/DATASUS) e do Instituto Brasileiro de Geografia e Estatística (IBGE). A cobertura vacinal foi estratificada por macrorregião e ano, sendo comparada à meta de 95% estabelecida pelo Ministério da Saúde. Observou-se que nenhuma macrorregião atingiu a meta preconizada durante o período analisado. A cobertura nacional apresentou redução progressiva de 73,44% em 2019 para 61,52% em 2021, seguida de recuperação parcial para 67,93% em 2022. Houve diferença estatisticamente significativa entre os anos avaliados. A região Norte apresentou os menores indicadores e as maiores reduções, enquanto a região Sul manteve os melhores níveis

[1] Fisioterapeuta, Mestrado em Ciências e Saúde pela Universidade Federal do Piauí, UFPI, Brasil.
[2] Biomédica, doutora em Biotecnologia pela Universidade Federal do Piauí (UFPI) com pós-doutorado em Imunologia de Tumores pela Universidade Estadual Paulista Júlio de Mesquita Filho (Unesp). Pesquisadora em Avaliação de Tecnologias em Saúde (DATS) do Instituto Nacional de Câncer (INCA).

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de cobertura. Apesar da melhora observada em 2022, os níveis vacinais permaneceram insuficientes, evidenciando desigualdades regionais e a necessidade de estratégias direcionadas para ampliar a vacinação e reduzir vulnerabilidades epidemiológicas.

PALAVRAS-CHAVE: Febre Amarela. Vacinação. Imunização. COVID-19. Brasil.

RESUMEN
La fiebre amarilla continúa siendo un importante problema de salud pública en Brasil, siendo la vacunación la principal estrategia para la prevención y el control de la enfermedad. Este estudio analizó la cobertura de vacunación contra la fiebre amarilla en las macrorregiones brasileñas entre 2019 y 2022, considerando el contexto de la pandemia de COVID-19 y sus posibles impactos sobre los servicios de inmunización. Se realizó un estudio observacional de enfoque ecológico utilizando datos secundarios provenientes del Sistema de Información del Programa Nacional de Inmunizaciones (SI-PNI/DATASUS) y del Instituto Brasileño de Geografía y Estadística (IBGE). La cobertura de vacunación se estratificó por macrorregión y año, y se comparó con la meta del 95% establecida por el Ministerio de Salud de Brasil. Se observó que ninguna macrorregión alcanzó la meta recomendada durante el período analizado. La cobertura nacional mostró una disminución progresiva, pasando del 73,44% en 2019 al 61,52% en 2021, seguida de una recuperación parcial hasta el 67,93% en 2022. Se identificaron diferencias estadísticamente significativas entre los años evaluados. La región Norte presentó las menores coberturas y las mayores reducciones, mientras que la región Sur mantuvo los niveles más elevados de cobertura vacunal. A pesar de la mejoría observada en 2022, los niveles de vacunación permanecieron por debajo de lo recomendado, lo que evidencia desigualdades regionales persistentes y la necesidad de implementar estrategias dirigidas para ampliar la vacunación y reducir las vulnerabilidades epidemiológicas.

PALABRAS CLAVE: Fiebre Amarilla. Vacunación. Inmunización. COVID-19. Brasil.

INTRODUCTION

Yellow fever is an acute infectious disease of viral etiology, endemic to tropical regions of Central America, South America, and Africa, and characterized as a vector-borne hemorrhagic fever[1]. The etiological agent is a virus belonging to the genus *Flavivirus*, transmitted by mosquitoes of the species *Aedes* spp. and *Haemagogus* spp., depending on the transmission cycle and geographical region[1,4].

The clinical spectrum of human infection is broad, ranging from asymptomatic forms to severe cases involving fever, myalgia, jaundice, arthralgia, and mucosal bleeding, which may progress to liver and kidney failure and result in death[2,3]. It is estimated that 15% to 50% of severe cases are fatal, giving the disease significant epidemiological relevance[1].

Transmission occurs through two distinct cycles. In the sylvatic cycle, arboreal vectors—*Haemagogus* spp. in the Americas and *Aedes* spp. in Africa—infect nonhuman primates, and humans become accidental hosts when entering forested areas. In the urban cycle, *Aedes aegypti* acts as a domestic vector, with humans serving as the primary hosts[4]. The control of urban

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outbreaks is particularly complex because of high population mobility and the challenges of raising awareness in large urban centers[4].

There is no specific antiviral treatment for yellow fever. Prevention is primarily based on vaccination, which provides long-lasting immunity after a single dose and is considered safe, effective, and low-cost[1,7]. Despite the availability of this vaccine, the disease remains a public health problem, partly because of underreporting in epidemiological surveillance systems and diagnostic difficulties resulting from nonspecific clinical presentations[8,9].

In Brazil, yellow fever is a notifiable disease, and vaccination is included in the National Immunization Program (Programa Nacional de Imunizações—PNI), with a target coverage of 95%. However, vaccination coverage in the country has shown progressive declines in recent decades, compromising the achievement of recommended targets and creating population-level vulnerabilities. Between July 2016 and May 2018, two major yellow fever outbreaks occurred, resulting in 2,045 confirmed cases and 677 deaths, respectively. This outcome was directly associated with low vaccination coverage in priority municipalities, where 47.4% of the 533 municipalities with a vaccination recommendation had coverage below 50% in 2016.

This scenario was further aggravated by the COVID-19 pandemic, during which demand for vaccination services against other diseases decreased substantially worldwide. National and international health agencies warned of the risks associated with this interruption, given that immunization is an essential strategy for preventing vaccine-preventable diseases[5]. Studies conducted in African countries demonstrated that delays in yellow fever vaccination campaigns in Ethiopia and Nigeria, attributed to the pandemic, resulted in a considerable increase in the risk of viral circulation[7]. In Brazil, it is estimated that approximately 40% of the population in the North and Central-West regions did not update their vaccination records during the pandemic, further deepening pre-existing vulnerabilities[6].

In addition to the pandemic context, structural and sociocultural factors have contributed to declining vaccination coverage. These include vaccine hesitancy, the growth of anti-vaccine movements—recognized by the World Health Organization (WHO) as one of the ten leading threats to global health—regional socioeconomic inequalities, and limitations in health-system infrastructure [10-11].

The lack of updated descriptive analyses of yellow fever vaccination coverage in Brazil, considering the impact of the COVID-19 pandemic and regional disparities, represents a relevant gap in epidemiological surveillance and immunization planning. Therefore, this study aimed to analyze yellow fever vaccination coverage across the Brazilian regions from 2019 to 2022,

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describing the temporal and regional variations observed before and during the COVID-19 pandemic.

METHODS

This was a descriptive observational study with an ecological approach and a temporal scope covering the period from 2019 to 2022. The data used were secondary data obtained from two publicly available sources: the Information System of the National Immunization Program (Sistema de Informações do Programa Nacional de Imunizações—SI-PNI), provided by the Department of Informatics of the Brazilian Unified Health System (DATASUS), and population data from the Brazilian Institute of Geography and Statistics (IBGE).

The unit of analysis was Brazil, stratified by macroregion—North, Northeast, Central-West, Southeast, and South—and by calendar year. Vaccination coverage for the single dose of the yellow fever vaccine and for booster doses administered at 15 months and 4 years of age was analyzed, according to the national vaccination schedule established by the PNI.

Vaccination coverage was calculated according to the method standardized by the SI-PNI. The numerator consisted of the number of yellow fever vaccine doses administered during the period and in the region analyzed, while the denominator corresponded to the population estimated by IBGE for the target age group of each dose. For booster doses, specific denominators were used for each age group—15 months and 4 years—because of population differences between the groups.

For the descriptive analysis, vaccination coverage was calculated by macroregion and year, along with absolute differences between consecutive years, expressed in percentage points. The distance between each region's coverage and the 95% target recommended by the Ministry of Health for all vaccines included in the basic vaccination schedule was also calculated and used as a reference for classifying coverage adequacy.

To compare vaccination coverage across the four years of the study period, the Friedman test was used. This nonparametric test is appropriate for paired samples and does not assume a normal distribution, with a significance level of 5% ($p<0.05$). For comparisons between consecutive pairs of years—2019–2020, 2020–2021, and 2021–2022—the Wilcoxon signed-rank test for paired samples was applied. Statistical analyses were performed using RStudio software, version 4.6.0, with the support of the *rstatix* package.

Because this study used publicly available secondary data without individual identification, approval by a Research Ethics Committee was not required, in accordance with

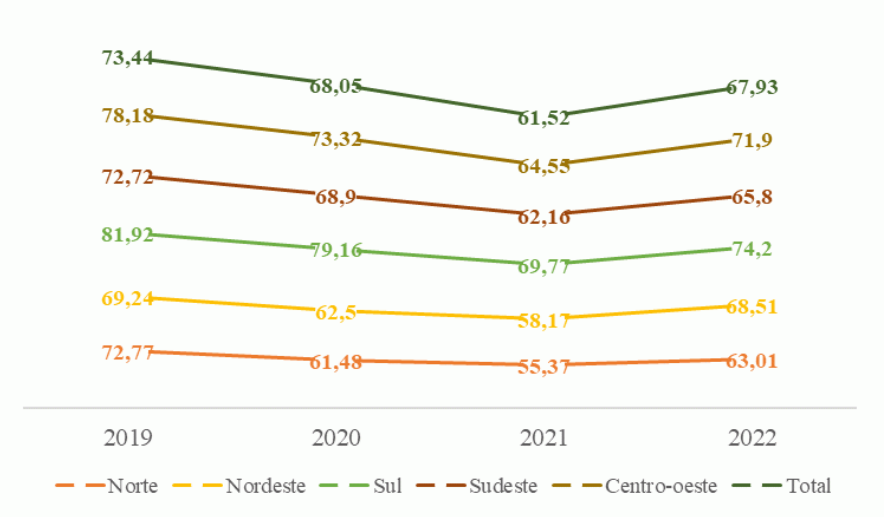
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Brazilian National Health Council Resolution No. 510/2016. All ethical principles were observed in the handling of the data.

RESULTS

From 2019 to 2022, yellow fever vaccination coverage remained below the 95% target recommended by the Ministry of Health in all Brazilian macroregions and in every year analyzed, with a statistically significant variation over the study period (Friedman test: χ^2=13.56; p=0.0036). The mean national coverage was 73.44% in 2019, 68.05% in 2020, 61.52% in 2021, and 67.93% in 2022, as shown in Graph 1.

Graph 1. Yellow fever vaccination coverage in the five macroregions of Brazil, 2019–2022.



Source: SI-PNI/DATASUS.

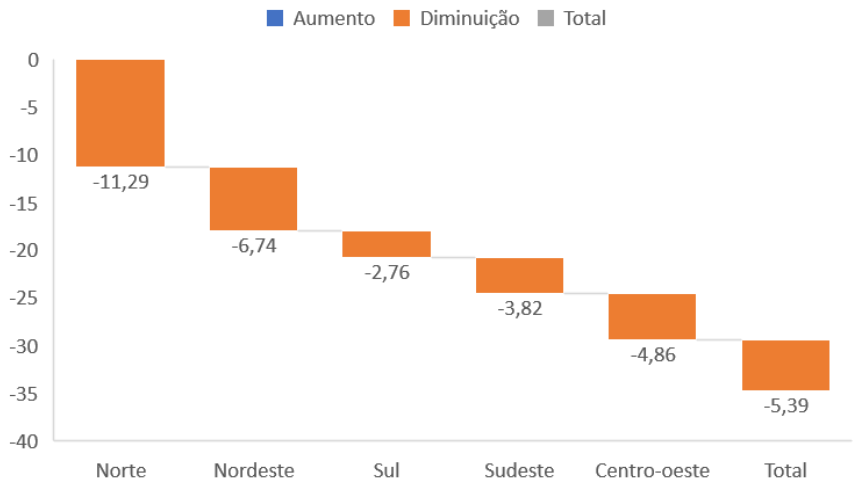
In 2019, the South region had the highest vaccination coverage (81.92%), followed by the Central-West (78.18%), Southeast (72.72%), North (72.77%), and Northeast (69.24%) regions. No region reached the 95% target. The smallest gap relative to the target was recorded in the South region (−13.08 percentage points), whereas the largest gap occurred in the Northeast (−25.76 percentage points).

Between 2019 and 2020, all macroregions experienced a reduction in vaccination coverage, with an average decrease of 5.89 percentage points. The North region recorded the largest decline (−11.29 percentage points), decreasing from 72.77% to 61.48%, whereas the South region showed the smallest decrease (−2.76 percentage points), as shown in Graph 2. The comparison between the two years did not reach statistical significance according to the Wilcoxon

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test (W=0.00; p=0.0625), which may be attributed to the small number of units of analysis (n=5 regions).

Graph 2 — Absolute difference in vaccination coverage between 2019 and 2020, by macroregion (percentage points).



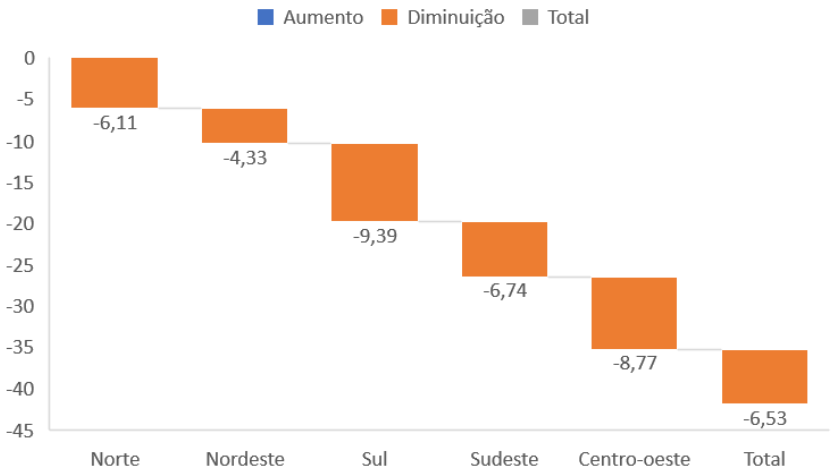
Source: SI-PNI/DATASUS.

In the following interval, between 2020 and 2021, a reversal in the regional pattern of decline was observed. The North (−6.11 percentage points) and Northeast (−4.33 percentage points) regions showed a reduction in the magnitude of the decline compared with the previous period, whereas the South (−9.39 percentage points), Central-West (−8.77 percentage points), and Southeast (−6.74 percentage points) regions experienced further decreases. The mean decline across regions during this interval was 7.07 percentage points, higher than that observed in the previous interval (5.89 percentage points), indicating an overall worsening in vaccination coverage. Graph 3 illustrates this pattern. The year 2021 represented the point of lowest coverage in all regions: North (55.37%), Northeast (58.17%), Southeast (62.16%), Central-West (64.55%), and South (69.77%). The difference relative to the 95% target ranged from −25.23 percentage points in the South to −39.63 percentage points in the North.

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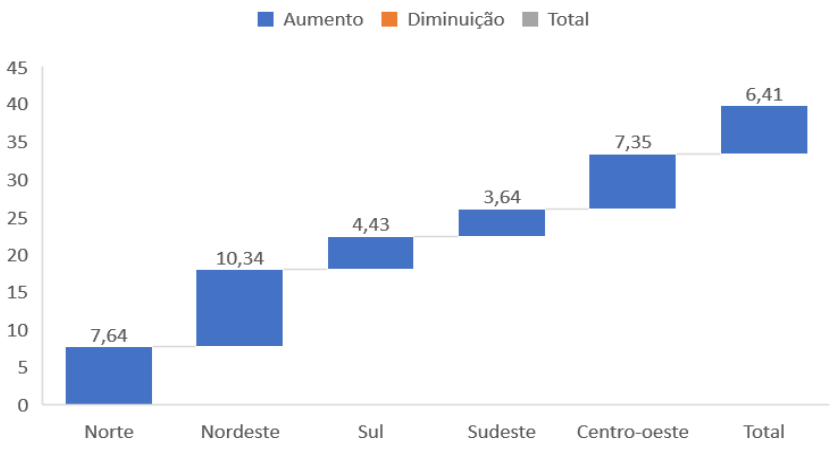
Graph 3 — Absolute difference in vaccination coverage between 2020 and 2021, by macroregion (percentage points).



Source: SI-PNI/DATASUS.

Between 2021 and 2022, all regions showed a recovery in vaccination coverage, with a mean increase of 6.68 percentage points. The Northeast recorded the greatest recovery (+10.34 percentage points, reaching 68.51%), followed by the North (+7.64 percentage points), Central-West (+7.35 percentage points), South (+4.43 percentage points), and Southeast (+3.64 percentage points). Despite this recovery, no region returned to its 2019 levels, and all remained below the 95% target at the end of the study period (Graph 4).

Graph 4 — Absolute difference in vaccination coverage between 2021 and 2022, by macroregion (percentage points).



Source: SI-PNI/DATASUS.

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Considering the entire period (2019–2022), the North region accumulated the greatest net loss in vaccination coverage (−9.76 percentage points), followed by the South (−7.72 percentage points), Southeast (−6.92 percentage points), and Central-West (−6.28 percentage points) regions. The Northeast recorded the smallest net variation (−0.73 percentage points), reflecting the substantial recovery observed in 2022. The standard deviation of regional vaccination coverage increased from 5.03 percentage points in 2019 to 7.43 percentage points in 2020, indicating that the COVID-19 pandemic deepened regional inequalities in vaccination coverage, with a disproportionate impact on the North region.

DISCUSSION

The results demonstrated that yellow fever vaccination coverage in Brazil remained below the 95% target recommended by the Ministry of Health in all macroregions and throughout the study period, with a progressive decline between 2019 and 2021 and a partial recovery in 2022. This pattern is consistent with the national trend of declining vaccination coverage observed over the past decade, which was exacerbated by the COVID-19 pandemic[12].

The North region showed the greatest decline in vaccination coverage between 2019 and 2020 (−11.29 percentage points), consistent with the findings of Benedetti et al. (2022), according to which approximately 40% of the population in the North and Central-West regions did not update their vaccination records during the pandemic, with particular vulnerability observed in the state of Roraima[6]. This situation is especially concerning in this macroregion, as the warm and humid climate, high vector density, and proximity to forested areas favor the circulation of the yellow fever virus, making the maintenance of high vaccination coverage an epidemiological priority.

Between 2020 and 2021, a reversal in the regional pattern was observed: whereas the North and Northeast regions experienced a reduction in the magnitude of the decline, the Central-West, Southeast, and South regions showed a further decrease, particularly the South (−9.39 percentage points). This dynamic suggests that the pandemic's impact on vaccination services was not homogeneous throughout the country and may reflect differences in the organization of local health systems, adherence to social isolation measures, and the capacity to maintain primary healthcare activities. Abreu et al. (2022) indicated that mandatory social isolation was one of the main determinants of low vaccination adherence during this period[12].

The recovery observed in all regions between 2021 and 2022, led by the Northeast (+10.34 percentage points), may reflect both the relaxation of pandemic-related restrictions and the catch-up vaccination campaigns implemented by the Ministry of Health during the post-

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pandemic period. Nevertheless, the fact that no region reached the 95% target at the end of the study period reinforces that this recovery was insufficient to reverse the accumulated losses.

The South region stood out for having the highest vaccination coverage throughout the study period, consistent with the findings of Gava et al. (2022), who identified better yellow fever surveillance and prevention indicators in regions with more structured primary healthcare services[17]. This finding suggests that the institutional capacity of local health services plays an important role in maintaining vaccination coverage, regardless of the national epidemiological context.

Among the structural and sociocultural factors contributing to the low vaccination performance identified in this study, vaccine hesitancy and the growth of anti-vaccine movements are particularly noteworthy. Milani and Busato (2021) indicated that vaccine refusal or hesitancy represents one of the main causes of declining vaccination coverage in Brazil, even in contexts in which vaccines are available in health services[18]. This phenomenon is recognized by the World Health Organization as one of the ten greatest threats to global health, as highlighted by Camargo Jr. (2020)[16]. The dissemination of misinformation and false news exacerbates this problem, creating barriers to vaccine acceptance among different population groups[14,15].

Access-related factors also exert a significant influence, particularly in more vulnerable regions. The distance between residences and vaccination sites, lack of transportation, long queues, and irregular availability of vaccines in primary healthcare services are documented obstacles that disproportionately affect rural and peripheral populations[5]. Marinho (2023) emphasized the need for continuous vaccination strategies that are not restricted to campaign periods, including an increase in the number of community health workers and improvements in the information infrastructure of the Brazilian Unified Health System (SUS)[5].

The weakening of the Brazilian Unified Health System during the pandemic, resulting from the massive mobilization of human and financial resources to address COVID-19, reduced the operational capacity of routine immunization services throughout the country. This impact is directly reflected in the vaccination coverage data analyzed in the present study[12,13].

This study has several limitations that should be considered when interpreting the results. Because secondary data from the SI-PNI were used, the analysis is subject to inconsistencies inherent in the information system, including underreporting of administered doses and potential recording errors. Additionally, the ecological design does not allow causal relationships to be established between the factors discussed and the observed variations in vaccination coverage; therefore, the findings are descriptive and hypothesis-generating.

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CONCLUSION

This study demonstrated that yellow fever vaccination coverage in Brazil remained below the 95% target recommended by the Ministry of Health in all macroregions and throughout the entire study period (2019–2022), with a progressive decline between 2019 and 2021 and a partial recovery in 2022 that was insufficient to reverse the accumulated losses. The North region stood out as the most vulnerable, recording the greatest decline between 2019 and 2020 (−11.29 percentage points), whereas the South region maintained the highest vaccination coverage throughout the period. The year 2021 represented the point of lowest vaccination coverage in all regions, coinciding with the period in which the COVID-19 pandemic had the greatest impact on health services and population mobility.

The findings reinforce that the decline in vaccination coverage is neither an isolated nor a homogeneous phenomenon. Rather, it is determined by the interaction of multiple structural, sociocultural, and contextual factors, including the weakening of primary healthcare services during the pandemic, vaccine hesitancy and refusal, the growth of anti-vaccine movements, regional inequalities in access to healthcare services, and the spread of misinformation. The persistence of insufficient vaccination coverage in regions with high vector density and ecological conditions favorable to the circulation of the yellow fever virus, such as the North region, represents a concrete risk of the resurgence of outbreaks and highlights the urgency of implementing differentiated immunization strategies in these areas.

The results of this study indicate the need for specific actions to restore vaccination coverage in Brazil, prioritizing regions with greater epidemiological vulnerability. Recommended measures include expanding and maintaining yellow fever vaccination campaigns beyond traditional seasonal periods; strengthening primary healthcare as the central pillar of the immunization strategy; investing in health education and combating misinformation; and improving vaccination information and surveillance systems to reduce underreporting and enable more accurate monitoring of vaccination coverage. Future studies incorporating analyses stratified by age group, sex, and socioeconomic conditions at the municipal level may enhance understanding of the determinants of the vaccination inequalities identified in this study.

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