ARTICLE
https://doi.org/10.22239/2317-269X.02509

Revista Visa em debate
sociedade, ciência & tecnologia

Meningococcal disease in Brazil (2015-2024): temporal trends and regional disparities in vaccination and hospitalizations

Doença meningocócica no Brasil (2015-2024): tendências temporais e disparidades regionais na vacinação e hospitalizações

Alisson Rafael de Oliveira Pereira*

Lucas Abreu Dias

Rodrigo Ferreira de Moura

Miriam Monteiro de Castro Graciano

Department of Medicine, Faculty of Health Sciences, Federal University of Lavras, Lavras, Brazil

* **E-mail:** alissonro.pereira@gmail.com

Received: Jun 30 2025
Approved: Jan 26 2026

How to cite: Pereira ARO, Dias LA, Moura RF, Graciano MMC. Meningococcal disease in Brazil (2015-2024): temporal trends and regional disparities in vaccination and hospitalizations. Vigil Sanit Debate, Rio de Janeiro, 2026, v.14: e02509. https://doi.org/10.22239/2317-269X.02509

ABSTRACT

Introduction: Understanding the epidemiological profile and regional differences over time of meningococcal infection allows identifying the most vulnerable patients, gaps in vaccination coverage, and disparities between regions, guiding epidemiological surveillance. **Objective**: To analyze temporal trends and disparities in meningococcal disease rates across Brazilian states from 2015 to 2024. **Methods:** An ecological study was conducted in Brazil and its states (2015–2024) through time-series analysis with choropleth maps to assess the spatial distribution of vaccination, hospitalizations, and death rates due to meningococcal infection. ARIMAX modeling analysis and joinpoint regression were performed to identify changes in trends. **Results:** A total of 9,077 hospitalizations and 1,118 deaths due to meningococcal infections were identified. Children under 10 years and adults up to 60 years were the most affected age groups. Spatially, Roraima and Bahia had the highest average hospitalization rates, whereas Alagoas and Espírito Santo had the lowest. Significant amplitude and trend changes were observed in Rio de Janeiro and Roraima. The ARIMAX model identified an increase in deaths and a reduction in hospitalizations associated with meningococcemia during the COVID-19 pandemic. **Conclusions:** Individuals whose skin colors were classified as Pardo according to IBGE criteria, mainly children, living in Roraima and Bahia, have the highest risk of hospitalization due to meningococcal infection. Amapá, Pará, and Roraima had the lowest means of vaccination coverage. The COVID-19 pandemic was associated with reduced diagnosis and increased mortality. Increases in vaccination coverage have a protective effect against hospitalization and death due to meningococcemia.

KEYWORDS: Meningococcal Infection; Meningococcal Vaccine; Meningitis; Epidemiology

RESUMO

Introdução: A compreensão do perfil epidemiológico e das diferenças regionais ao longo do tempo da infecção meningocócica permite identificar quais são os pacientes mais vulneráveis, as lacunas na cobertura vacinal e as disparidades entre regiões, orientando a vigilância epidemiológica. **Objetivo:** Analisar as tendências temporais e as disparidades nas taxas de doença meningocócica entre os estados brasileiros de 2015 a 2024. **Método:** Foi realizado um estudo ecológico no Brasil e em seus estados (2015–2024) por meio de análise de séries temporais e mapas coropléticos para avaliar a distribuição espacial da vacinação, hospitalizações e mortalidade por infecção meningocócica. Foi feito um modelo ARIMAX e regressão *joinpoint* para identificar mudanças nas tendências. **Resultados:** Foram identificadas 9.077 hospitalizações e 1.118 óbitos por infecção meningocócica. Crianças menores de 10 anos e adultos até 60 anos foram os grupos mais afetados. Espacialmente, Roraima e Bahia tiveram as maiores taxas de hospitalização, enquanto Alagoas e Espírito Santo, tiveram as menores. Mudanças significativas de amplitude e de tendência ocorreram no Rio de Janeiro e em Roraima. O modelo ARIMAX indicou aumento de óbitos e redução de hospitalizações por meningococcemia durante a pandemia de COVID-19. **Conclusões:** Indivíduos pardos, segundo critérios do IBGE, principalmente crianças residentes em Roraima e na Bahia, têm maior risco de hospitalização por infecção meningocócica. Amapá, Pará e Roraima apresentaram menores coberturas vacinais. A pandemia de COVID-19 foi associada à diminuição de diagnósticos e mortalidade elevada. O incremento na cobertura vacinal é associado a um efeito protetor contra hospitalização e morte por meningococcemia.

PALAVRAS-CHAVE: Infecção Meningocócica; Vacina Meningocócica; Meningite; Epidemiologia

INTRODUCTION

Despite advances in the diagnosis, management, and prevention of infectious diseases in Brazil, meningococcal disease remains an important cause of morbidity and mortality[1]. It affects all age groups, has an endemic distribution, and as it is transmitted through close interpersonal contact, it has seasonal patterns, with an increase in cases in the colder months[2]. The clinical spectrum of the disease is broad. The etiological agent, *Neisseria meningitidis*, is an aerobic Gram-negative diplococcus with invasive behavior, often associated with severe complications, permanent sequelae, and high mortality rates. The bacterium is classified into 13 serogroups, of which six (A, B, C, W, X, and Y) account for the majority of clinical cases.

As Moraes et al.[1] state, serogroup C has historically been the most prevalent in the regions of Brazil since 2005, a fact that led the country to become a pioneer in Latin America in incorporating the Men C vaccine into the national immunization program (PNI). While uncommon serogroups, such as A and W, are more frequently found in the African meningitis belt, Brazil's neighbours struggle with a similar colonization pattern, and countries such as Argentina and Chile have at some point in their recent history had serogroup C as the most prevalent serotype. The most recent schedule of the PNI provides inactivated vaccines specific to certain serogroups: the Men C vaccine, included in the children's routine since 2010 (with doses at 3 and 5 months), and the meningococcal ACWY vaccine, incorporated in 2020, indicated for adolescents aged 11–12 years and, according to the most recent actualization in 2025, replacing the Men C booster at 12 months[3]. The vaccine against serogroup B, however, is not yet offered by the Unified Health System (SUS).

As continuous epidemiological surveillance and constant updating of the disease profile are essential for planning effective public policies, this study aims to evaluate vaccine coverage and morbidity due to meningococcal disease in Brazil and its states, especially before the implementation of the first ACWY dose at 12 months to replace the Men C booster. This strategy allows identifying gaps in vaccination coverage, mapping regional vulnerabilities, and directing interventions compatible with the epidemiological reality of each territory[4].

The strengthening of anti-vaccine movements has been observed in several regions of the world, including Brazil[5], especially after the COVID-19 pandemic. The spread of misinformation, combined with institutional distrust and the politicization of science, has compromised vaccine uptake and threatened decades of achievements in the prevention of vaccine-preventable diseases[6]. This scenario poses a concrete risk to public health status and goals. As the drop in vaccination coverage may favor the resurgence of outbreaks and increase associated morbidity and mortality, it is imperative to conduct updated studies that analyze the epidemiological pattern of meningococcal disease in the post-pandemic scenario, aiming to assess the impacts of vaccine hesitancy and strengthen public immunization policies.

Thus, the present study aimed to describe the current epidemiological profile of meningococcal disease in Brazil by analyzing the demographic, clinical, and outcome data of hospitalized patients from the DATASUS system from 2015 to 2024. In addition, temporal trends, vaccination coverage, mortality rates, geographic distribution of cases, and the possible impact of the COVID-19 pandemic on the dynamics of the disease in the country were evaluated.

METHOD

This epidemiological analysis is an ecological observational study that uses two complementary approaches to evaluate hospitalization rates due to meningococcal infection in the last decade (Jan 2015 to Dec 2024) in Brazil: (a) time series modeling for national trends and (b) descriptive spatial analysis for interstate disparities. To prepare this article, the Reporting of studies Conducted using Observational Routinely collected Data (RECORD) statement[7] was used, an extension of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)[8], for reporting research conducted with secondary health data (Supplementary Table S1).

Data Sources and Inclusion Criteria

The study was conducted using data recorded in the Hospital Information System (SIH) of the SUS, the Mortality Information System (SIM-SUS), and the Information System (SI) of the PNI. All these data are available in the Informatics Department of the Unified Health System (DATASUS)[9]. The variables collected for analysis were the number of hospitalizations identified as meningococcal infection, number of deaths during hospitalizations, hospitalizations due to meningococcal infection by age group, sex, race, and vaccination coverage for meningococcal serogroup C. As an inclusion criterion, all data should have a primary diagnosis of meningococcal infection, defined in the system as A39.0–A39.9, according to the 10th revision of the International Classification of

Diseases (ICD-10), most recently grouped as 1C1C according to ICD-11. Population statistics related to age group, state, and sex were obtained from the Brazilian Institute of Geography and Statistics (IBGE).

Variables Analyzed

Hospitalization and mortality rates were defined as the ratio of affected patients (per capita of interest) to 100,000 inhabitants. By extension, we also stratified sex (male/female), age group (0-4 years, 5-9 years, 10-14 years, 15-19 years, 20-29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years, 70-79 years and 80 years or older), and region/state (North: AC, AP, AM, PA, RO, RR, and TO; Northeast: AL, BA, CE, MA, PB, PE, PI, RN, and SE; Southeast: ES, MG, RJ, and SP; Central-West: GO, MT, MS, and DF; SOUTH: PR, SC, and RS). To analyze age groups, the WHO definition was adopted as children (up to 10 years old), adolescents (10 to 19 years old), adults (20 to 59 years old), and the elderly (from 60 years old). All ratios have their denominators duly corrected by years and region. Missing data, such as when this denominator could not be obtained (such as for a self-reported race), rate analysis was not performed, and absolute values were presented. For vaccination rates, there was no need to operationalize since all the data were presented in the databases already as ratios.

Statistical Methods

SPSS v26.0 software was used for ARIMAX modelling and geospatial distribution analysis using the choropleth graph method of means. Time trend analysis was implemented to estimate mortality trends and annual percentual change (APC) using Joinpoint Trend Analysis Software v5.4, a logarithmic Poisson regression that applies the Monte Carlo permutation test[10]. Additionally, the average APC (AAPC) was evaluated, regardless of trend changes, and to determine whether, after the entire decade, the time series remained stationary (no statistical significance, with p-value > 0.05), had an upward trend (APC > 0, with p-value < 0.05), or showed a downward trend (APC < 0, with p-value < 0.05). For demographic data analysis, non-parametric tests, such as Kruskal-Wallis and post hoc analysis with Dunn tests, were performed to compare age groups.

To assess the impact of external variables, an autoregressive integrated moving average (ARIMA) model was fitted to the hospitalization rates and vaccination coverage time series. The parameters (p, d, q) were determined by analyzing the partial autocorrelation function (ACF/PACF) graphs after reaching a constant for differentiation, following the flowchart suggested by Schaffer et al., 2021[11]. This process resulted in parameters (0, 1, 0) for both variables. The Ljung-Box test was used to verify autocorrelation in the model residuals. A dummy variable (0 = pre-pandemic, 1 = pandemic period, 2020 and 2021) was included to test for the level of abrupt change during the COVID-19 pandemic, thus completing the ARIMAX model (0, 1, 0). Statistical significance was defined as a p-value < 0.05.

Given that all analyses were performed with secondary data available in the public domain, it was not necessary to register a protocol or obtain approval from the research ethics committee, as determined by Resolution Number 446 of the National Health Council on December 12, 2012[12].

RESULTS

Analysis of the clinical-demographic profile

A total of 9,077 hospitalizations and 1,118 deaths from meningococcal infections were reported throughout Brazil during the 10-year study period (2015-2024). The average number of hospitalizations per year was 908, with an average of 111 deaths per year, resulting in an average case fatality rate of 12.0%. Regarding the type of care, 8,294 (96.0%) hospitalizations were for emergency care.

The demographic analysis revealed a statistically significant difference between sexes, affecting males more than females (Wilcoxon Z = -2.8; p = 0.005), representing 54.0% of hospitalizations (4,913). Regarding the age groups, more hospitalization occurred in the pediatric age group. Children aged 0–9 years accounted for the largest volume of hospitalizations both in absolute numbers, with 3,211 hospitalizations (37.0%) and hospitalization rates (11.1 per 100,000 inhabitants), accounting for almost three times more hospitalizations than the subsequent age group (Supplementary Figure S1). In adolescents and young adults up to 39 years old, a decreasing pattern was observed, in both absolute and rate numbers, from 1,189 cases (3.8) in the 10-19 age group to 809 cases (2.4) between 30 and 39 years old. Middle-aged adults presented stationary data with mean rates of 2.5. However, elderly patients presented decreased absolute numbers with an increase in the hospitalization rate. Kruskal-Wallis test indicated a significant difference between age groups, and post hoc tests, such as the Dunn test, showed that the incidences in the groups of children and adults did not present a significant difference between each other but were equally more affected than the group formed by the less affected age groups. Similarly, no significant difference was found between the elderly and adolescents (Supplementary Table S3).

From an ethnographic perspective, pardo patients represented 40.1% of hospitalizations, followed by white patients (31.0%), black patients (3.2%), Asian patients (1.7%), and indigenous patients (0.4%). Unreported skin color patients represented 23.7%. Considering the temporal evolution, all groups showed an absolute decrease in 2020, and while the number of hospitalizations of unreported skin color patients maintained a downward trend, there was an increase in hospitalizations among pardos and white patients (Supplementary Figure S2).

Ecological spatial analysis

The spatial assessment revealed that among the 9,077 registered hospitalizations, the Brazilian states of the southeast region represented 38.3% of the cases, followed by the northeast (22.4%), south (19.6%), central-west (10.1%), and north (9.6%). When we compare the rates adjusted to the population, the relationship is reversed, and the southeast region assumes the lowest rate, with an incidence of 3.98 cases per 100,000 inhabitants, followed by the north region (4.84), northeast region (4.89), central-west region (5.64), and south region (5.9).

In each region, the states that contributed the most to the number of cases were Pará in the north (49.0%), Bahia in the northwest (27.0%), São Paulo in the southwest (55.0%), Rio Grande do Sul in the south (49.0%), and Goiás in the central-west region (49.0%). Adjusted to the population, the highest average rate by region occurred in Roraima (0.93), Bahia (0.38), São Paulo (0.43), Rio Grande do Sul (0.79), and Mato Grosso (0.67). The lowest average incidence occurred in Alagoas (0.26), Espírito Santo (0.28), Piauí (0.29), and Sergipe and Rio Grande do Norte (both with 0.30).

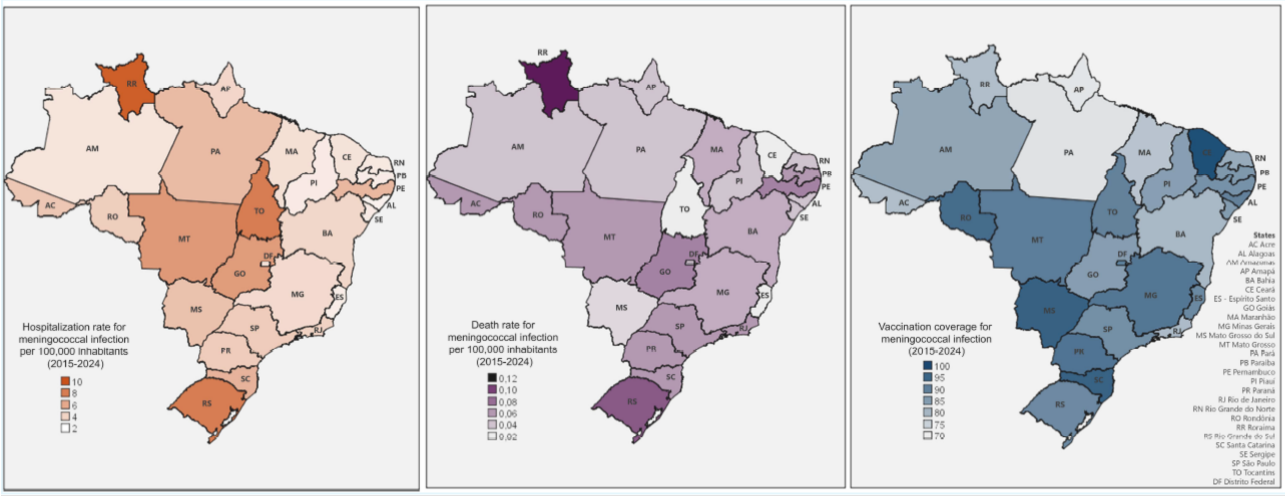
Regarding vaccination against Meningococcal C, the regions that maintained the highest average coverage were the south (91.8%), central-west (90.2%), southeast (86.5%), northeast (85.3%), and north (80.1%). The states with the highest average in the country were: Ceará (98.6%), Mato Grosso do Sul (95.5%), Santa Catarina (95.3%), Rondônia (93.4%), and Minas Gerais (91.5%). The lowest average vaccination coverage was observed in Amapá (71.3%), Pará (71.8%), Maranhão (77.2%), and Rio Grande do Sul (78.9%). Figure 1 shows the heat maps generated by the average vaccination coverage and the average vaccination rates of each state, with exact values presented in Table 1, while vaccination coverage variability and temporal trends by state are detailed in Table 2.

Spatial analysis by state revealed a large variation in hospitalization rates over the 10 years evaluated. States with the highest range of rates per 100,000 inhabitants were Roraima (RO) (0 to 2.3), Tocantins (TO) (0.25 to 2.04) and Rio Grande do Sul (RS) (0.47 to 1.08). States with the most stable rates were Ceará (CE) (0.12 to 0.50), Minas Gerais (MG) (0.20 to 0.49), and Paraná (PR) (0.21 to 0.77). Regarding variations in vaccination coverage, the greatest range was observed in Rio de Janeiro (RJ) (60.11 to 104.08), Roraima (RR) (62.7 to 93.3) and Amapá (AP) (49.8 to 96.3). The states that maintained the highest average coverage were Mato Grosso do Sul (MS) (95.4) and Santa Catarina (SC) (95.3). The lowest values were observed for Amapá (AP) (71.3), Pará (PA) (71.8), and Roraima (RR) (78.4) (Figure 2).

Temporal trend analysis

After first-order differentiation and logarithmic transformation, the Augmented Dickey-Fuller test indicated stationarity (ADF= -3.91, p = 0.01), validating the series modeling for subsequent analyses. Over the period evaluated, the hospitalization rate for meningococcal infection in Brazil showed two trend changes identified by Joinpoint regression in 2018 and 2021. Prior to 2018, the hospitalization rate decreased, with an annual percentage change (APC) of -7.16 (95%CI -15.8; 9.7), with no statistically significant trend (p = 0.39). After the first change point, the decline became more abrupt, with an APC of -21.23 (95%CI -27.5; 12.4), indicating a significant downward trend ($p < 0.01$). From 2021 onward, the second turning point, there was a trend reversal, with an APC of +18.95 (95%CI 6.4; 44.9), indicating a significant upward trend ($p < 0.01$). Considering the entire period, the average annual percentage change (AAPC) was -4.54 (95%CI -7.19; -1.4), revealing a significant downward trend ($p < 0.01$) (Figure 3).

Regarding the vaccination coverage time series, log transformation and first-order differentiation were also performed (ADF = -4.1; p = 0.01). The Joinpoint regression identified a turning point in 2021. The initial significant downward trend, with an APC of -4.19 (95%CI -7.7; -2.5, $p < 0.05$), was replaced by a significant upward trend, with an APC of +6.43 (95%CI 1.1; 14.5, $p < 0.05$). Overall, the APC was -0.77 (95%CI -2.1; 0.3, $p < 0.05$), showing no statistically significant trend when evaluated over the full period (Figure 3).



Source: Developed by the author (2025).

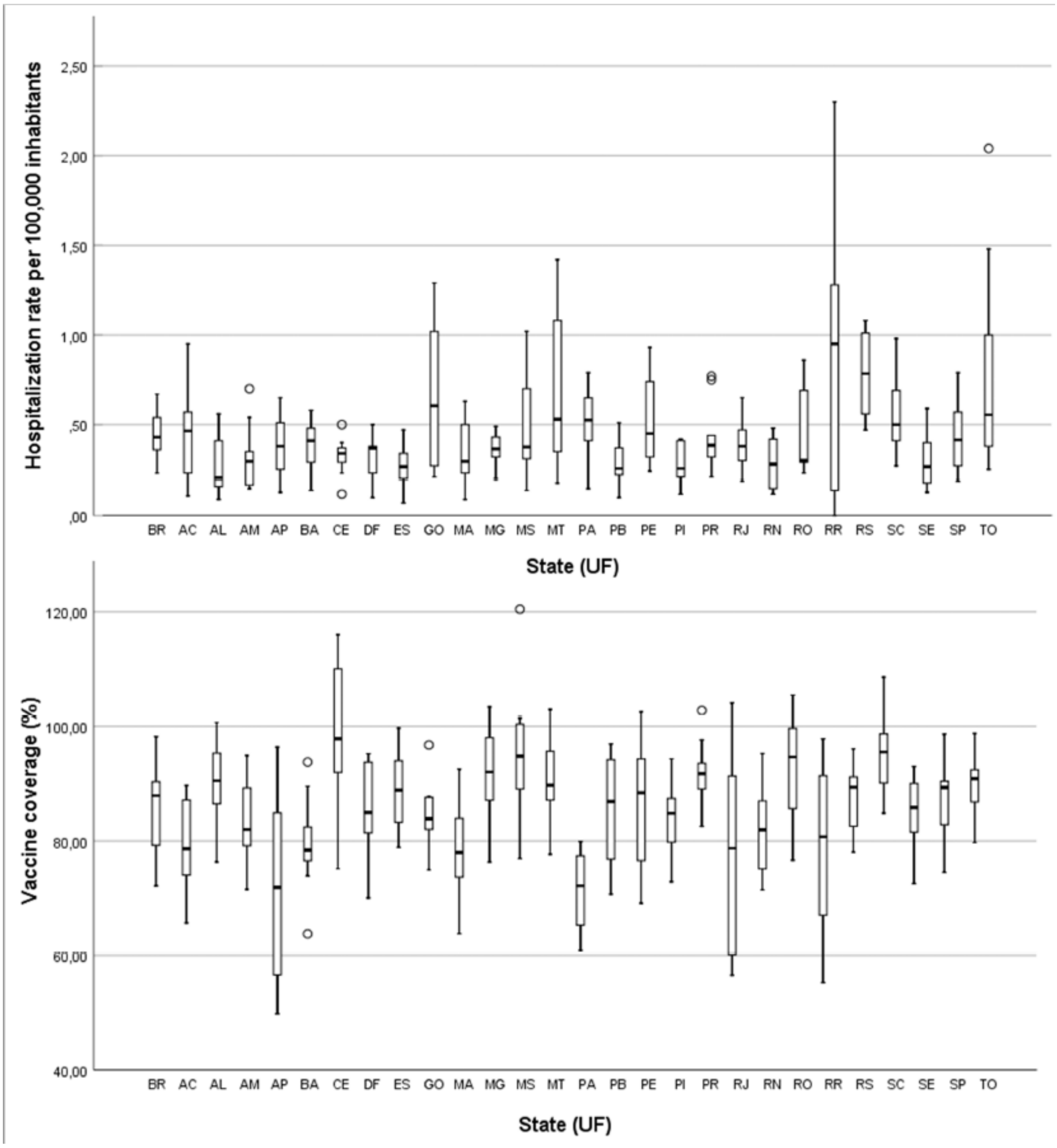
Figure 1. Choropleth map of MenC vaccine coverage, death, and hospitalization rates for meningococcal disease (2015-2024).

Table 1. Hospitalization rate for meningococcal infection by state, Brazil, 2015-2024.

Region and state (UF)	Hospitalization per 100,000 inhab. (range)	AAPC (95%CI)	Trend (p-value)
Brazil	0.44 (0.23-0.67)	-6.18 (-11.8; -1.9)	Decreasing (<0.01)
North			
Rondônia (RO)	0.42 (0.23-0.86)	16.24 (11.3; 21.9)	Increasing (<0.01)
Acre (AC)	0.45 (0.11-0.95)	-14.47 (-22.1; -6.9)	Decreasing (<0.01)
Amazonas (AM)	0.32 (0.17-0.7)	-11.07 (-14.9; -7.0)	Decreasing (<0.01)
Roraima (RR)	0.93 (0.00-2.30)	-13.25 (-46.6; 12.3)	Stationary (0.11)
Pará (PA)	0.50 (0.15-0.79)	-1.74 (-12.1; 9.0)	Stationary (0.7)
Amapá (AM)	0.39 (0.13-0.65)	-7.54 (-19.1; 5.1)	Stationary (0.18)
Tocantins (TO)	0.78 (0.25-2.04)	-18.33 (-22.9; -14.2)	Decreasing (<0.01)
Northeast			
Maranhão (MA)	0.34 (0.09-0.63)	-9.68 (-16.3; -3.7)	Decreasing (<0.01)
Piauí (PI)	0.29 (0.12-0.42)	0.59 (-2.9; 6.0)	Stationary (0.69)
Ceará (CE)	0.32 (0.12-0.50)	-0.26 (-13.3; 12.2)	Stationary (0.74)
Rio Grande do Norte (RN)	0.29 (0.12-0.48)	-3.93 (-11.4; 1.5)	Stationary (0.14)
Paraíba (PB)	0.28 (0.10-0.51)	-0.57 (-10.1; 8.8)	Stationary (0.73)
Pernambuco (PE)	0.52 (0.24-0.93)	-3.06 (-9.6; 2.8)	Stationary (0.27)
Alagoas (AL)	0.26 (0.09-0.56)	9.82 (-2.1; 19.2)	Stationary (0.1)
Sergipe (SE)	0.30 (0.13-0.41)	3.53 (-5.3; 14.8)	Stationary (0.29)
Bahia (BA)	0.38 (0.14-0.58)	-0.95 (-10.1; 5.7)	Stationary (0.65)
Southeast			
Minas Gerais (MG)	0.36 (0.20-0.49)	-1.70 (-6.4; 2.0)	Stationary (0.36)
Espírito Santo (ES)	0.28 (0.07-0.47)	6.67 (-4.6; 15.9)	Stationary (0.25)
Rio de Janeiro (RJ)	0.40 (0.26-0.65)	-5.57 (-9.0; -1.1)	Decreasing (<0.01)
São Paulo (SP)	0.43 (0.19-0.79)	-10.53 (-16.8; -5.6)	Decreasing (<0.01)
South			
Paraná (PR)	0.43 (0.21-0.77)	-7.58 (-10.3; -5.7)	Decreasing (<0.01)
Santa Catarina (SC)	0.54 (0.27-0.98)	-7.72 (-14.3; -0.9)	Decreasing (0.02)
Rio Grande do Sul (RS)	0.79 (0.47-1.08)	-7.95 (-12.7; -3.0)	Decreasing (<0.01)
Central-West			
Mato Grosso do Sul (MS)	0.48 (0.14-1.02)	-15.53 (-22.4; -8.7)	Decreasing (<0.01)
Mato Grosso (MT)	0.67 (0.18-1.42)	-16.51 (-23.7; -10.0)	Decreasing (<0.01)
Goiás (GO)	0.66 (0.21-1.29)	-8.68 (-15.8; -1.6)	Decreasing (0.01)
Distrito Federal (DF)	0.32 (0.10-0.50)	-0.60 (-9.6; 8.6)	Stationary (0.78)

Source: Developed by the author, 2025.
AAPC: Average Annual Percent Change; 95%CI: 95% Confidence Interval; UF: Federative Unit (Brazilian state); "-" indicates no joinpoint detected.

Most single states presented similar spatial patterns to the national one, maintaining the series stationary at the end of the period. In terms of hospitalization, eight states did not present joinpoints, 15 states presented a single joinpoint, and five states presented two joinpoints. Considering the entire period, 14 states presented a trend at the end (one ascending and 13 descending), while 13 remained stationary. Regarding vaccination coverage, only one state presented no joinpoints and three states had two joinpoints, whereas the remaining 23 states had only one change in trend. The complete information on the trends in each state is summarized in Tables 1 and 2. Detailed information about the joinpoints is available in Supplementary Table S2.



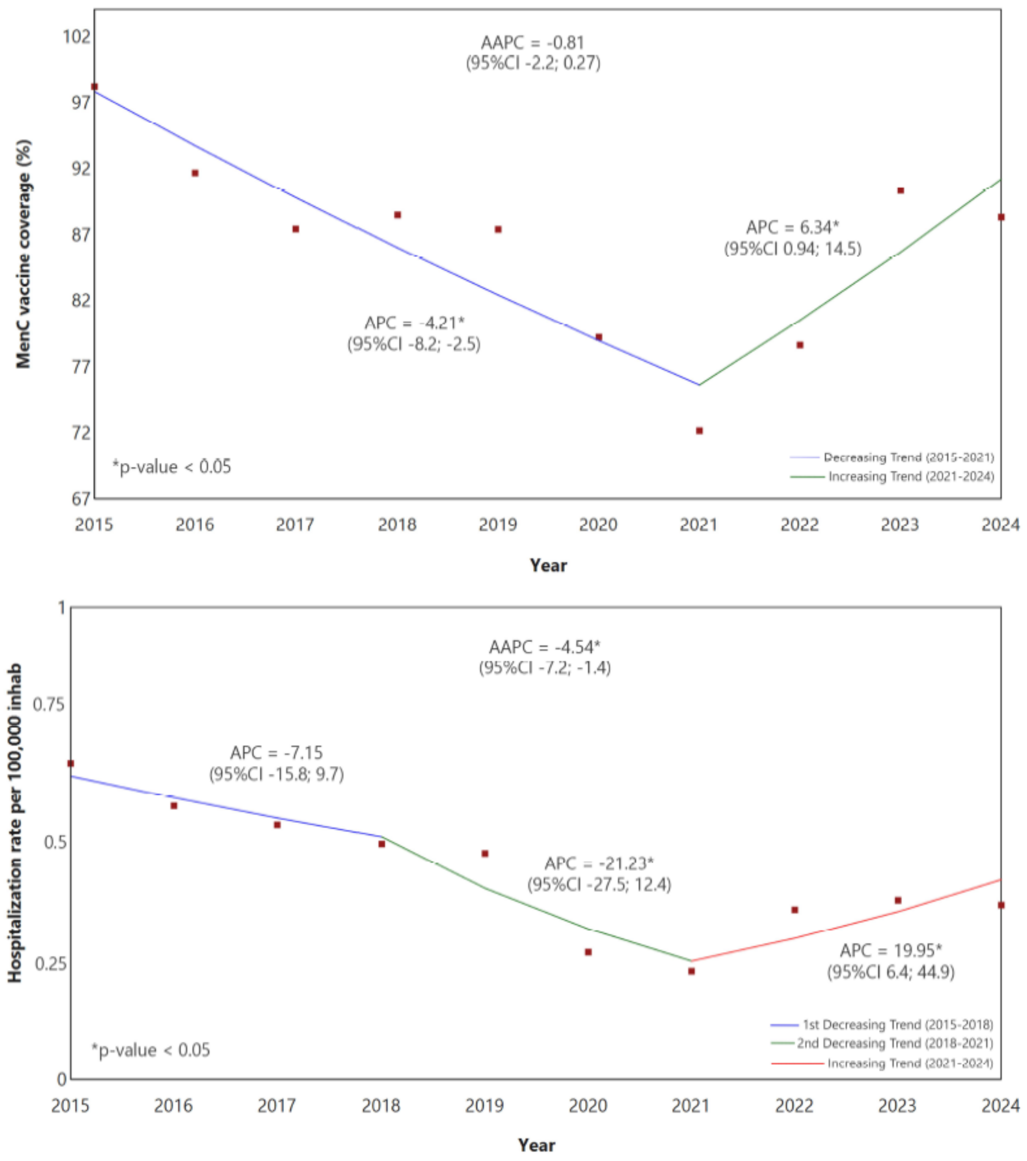
Source: Developed by the author (2025).

Figure 2. Boxplots of MenC vaccine coverage and hospitalization rate for meningococcal disease per state (2015-2024).

Temporal analysis of covariates

To construct the ARIMAX model, the hospitalization rate underwent first-order differentiation to induce stationarity (ADF = -4.0; p = 0.02). The ACF/PACF graph was visually inspected, without residual partial autocorrelation. Thus, setting AR = 0 and MA = 0, a model of type (p, d, q) was estimated as ARIMAX (0, 1, 0) for hospitalization due to meningococcal infection. Model adequacy metrics were Bayesian information criterion (BIC = -5.79), Ljung-Box test (Q = 6.2; p = 0.51), and R^2 = 0.92. The residual ACF/PACF plots confirmed the adequacy of the model (Supplementary Figure S3). The COVID-19 period was set as a dummy variable in the ARIMAX (0, 1, 0) model analysis, which revealed a significant impact of this variable on the hospitalization rate series (-0.146; p < 0.01). Vaccination coverage was significant at lag 1 (-0.008; p < 0.01), being inversely proportional to the hospitalization rate.

As for the model representing the death rate, the settings were similar, generating an ARIMAX (0, 1, 0) model. The model metrics were as follows: BIC= -6.7, Ljung-Box Q = 5.1.0; (p = 0.65), R^2=0.4. The residual ACF/PACF plots confirmed the adequacy of the model (Supplementary Figure S4). Although the COVID-19 period was related to a decrease in reported deaths by meningococcal disease, it was not statistically significant (-0.03; p = 0,15).



Source: Developed by the author, 2025.

Figure 3. Joinpoints and trends on MenC vaccine coverage and hospitalization rate for meningococcal disease (2015-2024).

DISCUSSION

Our study highlights important components for understanding hospitalization rates due to meningococcal infection in Brazil. Regarding the clinical and demographic profiles of patients, males were more affected, especially in the age groups of children under 10 years and adults aged 20 to 60 years. Pardos and white patients represented the majority of those infected. In particular, Pará and Bahia contributed the largest number of cases, although proportionally, the highest hospitalization rates belong to Roraima and Rio Grande do Sul. Unsurprisingly, the lowest average vaccination coverage percentages for meningococcal C vaccine were found in some of these states. Deaths due to meningococcemia were also predominant in these locations, with Roraima and Rio Grande do Sul presenting the highest rates. Temporarily, Brazil's average hospitalization rate underwent two trend changes, with a decrease in 2018 and an increase in 2021. Meanwhile, the country's average vaccination coverage rate underwent only one change, replacing the decreasing trend with an increasing trend from 2021 onwards.

Previous studies across the globe have found that the highest incidence of invasive meningococcal disease occurs in infants aged 0-5 years, with a decrease in older children and adolescents, spiking again in young adults, followed by a decreasing pattern in the elderly[13], which is similar to ours finding in Brazil, both at the state and country levels. The overall incidence of meningococcal disease per 100,000 inhabitants varies worldwide, ranging from as low as 0.03 in Saudi Arabia to as high as 2.5 in New Zealand[14]. In our study, in Brazil we found a mean incidence rate of 0.44 in the last 10

Table 2. Vaccination coverage for meningococcal infection by state, Brazil, 2015-2024.

Region and state (UF)	Vaccination Coverage (range)	AAPC (95% CI)	Trend
Brazil	86.19 (72.2-98.2)	-0.77 (-2.1; 0.3)	Stationary (0.13)
North			
Rondônia (RO)	93.40 (76.6-105.5)	-0.64 (-1.3; 0.1)	Stationary (0.08)
Acre (AC)	78.47 (65.6-87.1)	-0.02 (-2.1; 1.7)	Stationary (0.85)
Amazonas (AM)	82.92 (71.5-94.9)	-0.08 (-2.4; 1.7)	Stationary (0.73)
Roraima (RR)	78.49 (55.2-93.3)	-4.18 (-6.8; -2.7)	Decreasing (<0.01)
Pará (PA)	71.86 (65.1-79.0)	0.99 (-0.7; 2.4)	Stationary (0.25)
Amapá (AP)	71.32 (49.8-96.3)	-2.51 (-5.7; -0.1)	Stationary (0.44)
Tocantins (TO)	89.54 (82.3-98.7)	-0.79 (-1.8; 0.17)	Stationary (0.1)
Northeast			
Maranhão (MA)	77.28 (63.7-92.5)	0.21 (-1.7; 1.7)	Stationary (0.87)
Piauí (PI)	84.25 (72.8-94.3)	1.55 (-0.83; 3.3)	Stationary (0.21)
Ceará (CE)	98.62 (75.1-115.9)	-1.24 (-1.9; -0.5)	Decreasing (<0.01)
Rio Grande do Norte (RN)	82.02 (73.59-95.23)	-0.86 (-3.1; 2.6)	Stationary (0.68)
Paraíba (PB)	85.44 (70.7-96.9)	-1.79 (-5.9; 2.5)	Stationary (0.32)
Pernambuco (PE)	86.58 (69.1-102.5)	-1.37 (-3.2; 0.1)	Stationary (0.06)
Alagoas (AL)	89.52 (76.3-100.0)	-0.19 (-2.5; 1.6)	Stationary (0.68)
Sergipe (SE)	84.75 (72.5-92.9)	0.25 (-1.8; 1.7)	Stationary (0.89)
Bahia (BA)	79.65 (63.7-93.7)	0.23 (-1.5; 1.5)	Stationary (0,82)
Southeast			
Minas Gerais (MG)	91.48 (76.3-103.8)	-0.51 (-2.7; 1.4)	Stationary (0.39)
Espírito Santo (ES)	88.27 (78.4-99.6)	-0.09 (-1.7; 0.9)	Stationary (0.79)
Rio de Janeiro (RJ)	78.95 (60.11-104.1)	-2.27 (-29.0; -1.7)	Decreasing (<0.01)
São Paulo (SP)	87.19 (74.5-98.6)	-0.70 (-2.7; 0.7)	Stationary (0.22)
South			
Paraná (PR)	91.98 (86.5-102.7)	-0.39 (-2.1; 0.9)	Stationary (0.36)
Santa Catarina (SC)	95.31 (84.8-108.5)	-1.19 (-2.6; 0.2)	Stationary (0.02)
Rio Grande do Sul (RS)	88.19 (78.0-96.0)	0.04 (-1.7; 1.3)	Stationary (0.87)
Central-West			
Mato Grosso do Sul (MS)	95.49 (76.9-120.4)	-1.18 (-3.4; 0.4)	Stationary (0.14)
Mato Grosso (MT)	90.45 (77.6-102.9)	-0.22 (-2.3; 1.3)	Stationary (0.62)
Goiás (GO)	84.51 (74.9-96.7)	-1.26 (-2.4; -0.3)	Decreasing (<0.01)
Distrito Federal (DF)	90.68 (70.0-146.8)	-0.85 (-4.6; 2.3)	Stationary (0.46)

Source: Developed by the author, 2025.
AAPC: Average Annual Percent Change; 95%CI: 95% Confidence Interval; UF: Federative Unit (Brazilian state); "-" indicates no joinpoint detected.

years, with the highest hospitalization rate in 2015 (0.67) and the lowest incidence in 2021 (0.23). These results are consistent with those reported in a systematic review conducted by Presa et al.[2]. Comparatively, Europe had an overall notification rate of 0.62 in 2017, whereas countries such as the United States of America and Russia presented rates of 0.11 and 0.58, respectively[14].

As 2020 was the year with the lowest incidence rates in other countries, other studies also aimed to investigate whether and how the COVID-19 pandemic may have influenced meningococcal disease epidemiology. Our ARIMAX model found that a COVID dummy variable in the pandemic years was associated with a diminished 0.15 units in hospitalization rates but was not significant in influencing death rates by meningococcal disease ($p > 0.05$). Two main reasons may explain these behaviors: subdiagnosis of meningococcal infection in a scenario of overloaded health systems, focused on providing support to the specific issues related to COVID-19[15], generating a notification bias; and smaller transmission rates due to lockdown measures, which minimized close contact and limited social gatherings that normally would cause meningococcal transmission[16], even though this second hypothesis seems to be less probable, since there was no significant change to the trend of mortality due to meningococcemia.

Vaccine coverage was also identified in the ARIMAX model as a significant covariate for hospitalizations and deaths in our model. This inverse correlation has already been proven in multiple settings[17,18], and even with Brazil's vaccination being mainly focused on MenC (although Men ACWY has also been recommended for teenagers since 2020), this vaccination schedule has proven not only to be effective in reducing all types of hospitalization and deaths by meningococcemia but also indirectly protect unvaccinated subjects[19].

In this context, our regression for vaccine coverage found that until 2021, there was a significant downward trend, possibly due to changes in behaviors towards to vaccination acceptance, such as risk perceptions, distrust, and perceived constraints[20], to the rise of anti-vaccine groups[6], increasing vaccine hesitancy, a concept aggravated by the coronavirus pandemics[21] that resulted in less vaccination rates[22]. Joinpoint analysis found in 2021 marks a change to a significant upward trend motivated by pro-vaccine campaigns and catch-up vaccinations after the COVID-19 pandemic[23]. Hospitalization rates seem to have followed a similar path, although their series had a first joinpoint in 2018, changing the stationary status into a significant downward trend that achieved its lowest values in 2020 and 2021, probably COVID-19-related. Although statistical significance was not found for a downward trend in the previous section of the series, there was an APC of - 7.15 that remained stable until 2019. The lack of statistical power due to the low number of samples before the joinpoint may explain why this initial trend was not significant[24]. For the second joinpoint, in 2021, the change was most likely related to COVID-19. As 2021 was the year that COVID-19 vaccination started in Brazil, patients were also slowly retaking their routines, reversing the trend described by Alderson et al.[16] leading to transmission rates increasing again.

Another important hypothesis that may explain the upward trend observed in the hospitalization series is a more robust surveillance and a better-established laboratory infrastructure. As the diagnosis can be confirmed earlier, patients are more hospitalized to obtain treatment[25]. The COVID-19 pandemic may have contributed to the development of better infrastructure and laboratory accessibility. As Sáfadi et al.[25] stated, the notification of meningococcal disease is already compulsory in Latin America, and although surveillance may be inconsistent, many improvements, such as more reliable surveillance systems and accurate detection techniques, have been implemented to varying degrees.

Considering regional disparities, the key explanatory factors remain access to health services, socioeconomic factors, disinformation, and cultural beliefs[26]. When specifically looking into meningococcal disease, Parik et al.[27] described that "in many areas of the world, the gold-standard method of active surveillance and laboratory confirmation with strain characterisation is not possible". As Brazil is a continental-sized country, the most distant states may suffer from a lack of infrastructure or patients' access to the health system; therefore, it may not be possible to determine the serogroup responsible for the meningococcal disease.

Even when better diagnostic tools are available, a large number of confirmed cases cannot be serogroup-tested. The number of each serogroup could be even larger when considering that unconfirmed cases would also not add up to these statistics. A literature review published by Santayana et al.[14] pointed out that in 2018, 52% of invasive meningococcal disease in Brazil was non-groupable. The most recent data, from the meningitis epidemiological panel of 2024, revealed that of the 819 cases of meningococcal disease reported, 270 were identified as serogroup B, 162 as serogroup C, 30 as serogroup W, 33 as serogroup Y, and 218 were untyped, reducing the estimates of unknown serology to 30%[28].

When considering immunization and primary prevention, there is a major mismatch between epidemiology and vaccine availability according to the serogroups. Historically, the MenC vaccine was first introduced in the PNI in late 2010 due to an important rise in the proportion of cases of serogroup C. The effects were almost immediate in reducing MenC cases, especially among those < 2 years old[29,30]. Ten years later, in 2020, MenACWY replaced MenC in adolescents, and now, in 2025, MenACWY also replaces the booster dose at 12 months[3]. The relatively early introduction of this conjugate vaccine into the calendar might explain why other serotypes, such as A and W, responsible for substantial proportions of cases across Africa and parts of Asia[27], do not represent a major threat. Currently, Brazil faces the same predominant serogroup as Europe and North America[27], as serogroup B is responsible for most meningococcal infections. In 2024, almost 33% of reported cases of meningococcal disease were caused by MenB, whereas MenC accounted for 19% of cases. However, a specific vaccine is not yet offered by the SUS. This mismatch may be the main reason for the recurring upward trend in hospitalizations and deaths due to meningococcal disease, even when the vaccine coverage for MenC is high.

The major limitations of this study are related to notification and data bias, as its main source of data depends on secondary data from the Brazilian surveillance system. Another key limitation that must be considered is that ARIMAX models can detect correlation but cannot establish direct causality. Other non-included variables can also affect the time series, explaining possible discrepancies between the model and real data. The lack of specific data on serogroups for all the time period also limits the interpretation of vaccine coverage as a predictor of hospitalizations for meningococcal disease, as MenC coverage is the only available data. Even if MenACWY was considered, both vaccines do not provide protection against the now most prevalent serogroup B. Finally, we recommend new studies to investigate specific details on epidemiologic profile per serogroup types and evaluate the viability of a MenB vaccine being included in the PNI.

CONCLUSIONS

This study provides a novel, integrated analysis of a decade of national data and quantifies the concurrent impact of vaccination efforts and the COVID-19 pandemic on meningococcal disease trends across all Brazilian states. There were substantial variations in both vaccination coverage and hospitalization rates between 2015 and 2024. Despite the recent increase in vaccination, the average coverage has remained below that of the previous decade, warranting closer epidemiological monitoring. Marked regional disparities were identified, and reinforcement of vaccination through new campaigns is recommended, particularly in Roraima and Rio Grande do Sul, which showed the lowest coverage and highest hospitalization rates. These campaigns should be particularly focused on Pardo children, who represent the most vulnerable sociodemographic group. Strengthening the laboratory net infrastructure for sustained surveillance, especially to better characterize the Brazilian profile of meningococcus serotypes, should also be prioritized.

SUPPLEMENTARY FILES

Supplementary Tables (S1-S3) and Figures (S1-S4) referenced in the study are available in the Figshare repository at: https://doi.org/10.6084/m9.figshare.30842948

REFERENCES

1. Moraes C, Moraes JC, Silva GDM, Duarte EC. Evaluation of the impact of serogroup C meningococcal disease vaccination program in Brazil and its regions: a population-based study, 2001-2013. Mem Inst Oswaldo Cruz. 2017;112(4):237-46. https://doi.org/10.1590/0074-02760160173
2. Presa JV, Almeida RS, Spinardi JR, Cane A. Epidemiological burden of meningococcal disease in Brazil: a systematic literature review and database analysis. Int J Infect Dis. 2019;80:137-46. https://doi.org/10.1016/j.ijid.2019.01.009
3. Ministério da Saúde (BR). Nota técnica N° 77/2025-CGICI/DPNI/SVSA/MS: substituição da dose de reforço da vacina meningocócica C pela vacina meningocócica ACWY. Brasília: Ministério da Saúde; 2025[access Sept 23, 2025]. Available from: https://www.gov.br/saude/pt-br/centrais-de-conteudo/publicacoes/notas-tecnicas/2025/nota-tecnica-no-77-2025-cgici-dpni-svsa-ms.pdf/
4. Rouquayrol MZ, Silva MGC. Rouquayrol: epidemiologia & saúde. Rio de Janeiro: Medbook; 2018.
5. Vignoli RG, Silva RCD, Maran MFIDA, Vitoriano MCCP. Movimento antivacina e hesitação vacinal na COVID-19: reflexões e percepções para a ciência da informação. Inf Inf. 2022;27(1):457-84. https://doi.org/10.5433/1981-8920.2022v27n1p457
6. Falcão HG, Monari AC, Sacramento I, Maués C. “Meus filhos não serão cobaias”: cismas e discursos antivacinação infantil pós-pandemia de Covid-19. Horiz Antropol. 2024;30(69):1-33. https://doi.org/10.1590/1806-9983e690408
7. Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I et al. The REporting of studies conducted using observational routinely-collected health data (Record) statement. PLOS Med. 2015;12(10):1-22. https://doi.org/10.1371/journal.pmed.1001885
8. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The strengthening the reporting of observational studies in epidemiology (Strobe) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008;61:344-9. https://doi.org/10.1016/j.jclinepi.2007.11.008
9. Ministério da Saúde (BR). Datasus: informações de saúde: morbidade hospitalar do SUS (SIH/SUS). Brasília: Ministério da Saúde; 2025[access May 25, 2025]. Available from: https://datasus.saude.gov.br/informacoes-de-saude-tabnet/
10. Bando DH, Brunoni AR, Fernandes TG, Benseñor IM, Lotufo PA. Suicide rates and trends in São Paulo, Brazil, according to gender, age and demographic aspects: a joinpoint regression analysis. Rev Bras Psiq. 2012;34:286-93. https://doi.org/10.1016/j.rbp.2012.02.001
11. Schaffer AL, Dobbins TA, Pearson SA. Interrupted time series analysis using autoregressive integrated moving average (ARIMA) models: a guide for evaluating large-scale health interventions. BMC Med Res Methodol. 2021;21(58):1-21. https://doi.org/10.1186/s12874-021-01235-8
12. Ministério da Saúde (BR). Resolução CNS Nº 466, de 12 de dezembro de 2012. Aprova diretrizes e normas regulamentadoras de pesquisas envolvendo seres humanos; revoga as RESoluções Nº 196/96, 303/00 404/08. Diário Oficial União. Dec 13, 2012.
13. Pelton SI. The global evolution of meningococcal epidemiology following the introduction of meningococcal vaccines. J Adol Health. 2016;59:S3-S11. https://doi.org/10.1016/j.jadohealth.2016.04.012
14. Pardo CS, Htar MTT, Findlow J, Balmer P. Epidemiology of invasive meningococcal disease worldwide from 2010–2019: a literature review. Epidemiol Infect. 2023;151(57):1-7. https://doi.org/10.1017/S0950268823000328
15. Borges PKDO, Martins CM, Stocco C, Zuber JFS, Borges WS, Muller EV et al. Impacto da COVID-19 sobre doenças de notificação compulsória: um estudo de série temporal. Rev Escol Enferm USP. 2024;58:1-10. https://doi.org/10.1590/1980-220x-reeusp-2024-0098pt

16. Alderson MR, Arkwright PD, Bai X, Black S, Borrow R, Caugant DA et al. Surveillance and control of meningococcal disease in the COVID-19 era: a global meningococcal initiative review. J Infect. 2022;84(3):289-96. https://doi.org/10.1016/j.jinf.2021.11.016
17. Helena LO, Jauregui B, Carvalho AF, Giglio N. Impact and effectiveness of meningococcal vaccines: a review. Rev Panam Salud Pública. 2017;41:1-19. https://doi.org/10.26633/RPSP.2017.158
18. Shin T, Wells CR, Shoukat A, Potter-Schwartz L, Langevin E, Langley JM et al. Quadrivalent conjugate vaccine and invasive meningococcal disease in US adolescents and young adults. JAMA Netw Open. 2024;7(11):1-10. https://doi.org/10.1001/jamanetworkopen.2024.43551
19. Trotter CL, Gay NJ, Edmunds WJ. Dynamic models of meningococcal carriage, disease, and the impact of serogroup C conjugate vaccination. Am J Epidemiol. 2005;162(1):89-100. https://doi.org/10.1093/aje/kwi160
20. Habersaat KB, Jackson C. Understanding vaccine acceptance and demand: and ways to increase them. Bundesgesundheitsbl. 2020;63:32-9. https://doi.org/10.1007/s00103-019-03063-0
21. Souto EP, Fernandez MV, Rosário CA, Petra PC, Matta GC. Hesitação vacinal infantil e COVID-19: uma análise a partir da percepção dos profissionais de saúde. Cad Saúde Pública. 2024;40(2):1-12. https://doi.org/10.1590/0102-311xpt061523
22. Procianoy GS, Rossini Junior F, Lied AF, Jung LFPP, Souza MCSCD. Impacto da pandemia do COVID-19 na vacinação de crianças de até um ano de idade: um estudo ecológico. Ciênc Saúde Colet. 2022;27(3):969-78. https://doi.org/10.1590/1413-81232022273.20082021
23. Wu J, Yu W, Cao L, Cao L, Rodewald L, Ye J et al. Effectiveness of catch-up vaccinations after COVID-19 containment: China, 2020. China CDC Week. 2020;2(50):968-74. https://doi.org/10.46234/ccdcw2020.262
24. Bates BT, Dufek JS, Davis HP. The effect of trial size on statistical power. Med Sci Sports Exerc. 1992;24(9):1059-65.
25. Sáfadi MAP, González-Ayala S, Jäkel A, Wieffer H, Moreno C, Vyse A. The epidemiology of meningococcal disease in Latin America 1945–2010: an unpredictable and changing landscape. Epidemiol Infect. 2013;141(3):447-58. https://doi.org/10.1017/S0950268812001689
26. Roberti J, Ini N, Belizan M, Alonso JP. Barriers and facilitators to vaccination in Latin America: a thematic synthesis of qualitative studies. Cad Saúde Pública. 2024;40(6):1-18. https://doi.org/10.1590/0102-311xen165023
27. Parikh SR, Campbell H, Bettinger JA, Harrison LH, Marshall HS, Martinon-Torres F et al. The everchanging epidemiology of meningococcal disease worldwide and the potential for prevention through vaccination. J Infect. 2020;81:483-98. https://doi.org/10.1016/j.jinf.2020.05.079
28. Ministério da Saúde (BR). Painel meningite. Brasília: Ministério da Saúde; 2025[accessed May 28, 2025]. Available from: https://www.gov.br/saude/pt-br/composicao/svsa/cnie/painel-meningite/painel-meningite-
29. Nunes AA, Abreu AJL, Cintra O, Cintra MACT, Coelho EB, Barros ENC. Meningococcal disease epidemiology in Brazil (2005–2018) and impact of MenC vaccination. Vaccine. 2021;39(3):605-16. https://doi.org/10.1016/j.vaccine.2020.11.067
30. Andrade AL, Minamisava R, Tomich LM, Lemos AP, Gorla MC, Cunto Brandileone MC et al. Impact of meningococcal C conjugate vaccination four years after introduction of routine childhood immunization in Brazil. Vaccine. 2017;35(16):2025-33. https://doi.org/10.1016/j.vaccine.2017.03.010

Acknowledgments

This work has been supported by the following Brazilian research agency: National Council for Scientific and Technological Development – CNPq.

Author Contribution

Pereira ARO - Conception, planning (study design), acquisition, analysis, data interpretation and writing of the work. Moura RF - Planning (study design), analysis. Dias LA - Data interpretation. Graciano MMC - Reviewed the manuscript. All the authors approved the final version of the paper.

Conflict of Interest

Authors have no potential conflict of interest to declare, related to this study's political or financial peers and institutions.