

Spatiotemporal analysis of meningitis mortality in Brazil between 2001 and 2021

Análise espaço-temporal da mortalidade por meningite no Brasil entre 2001 e 2021.

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ABSTRACT

Introduction: Brazil shows heterogeneous regional patterns of meningitis mortality. Between 2001 and 2021, 22,764 deaths were recorded nationwide.

Objective: To analyze the spatial distribution and epidemiological profile of meningitis-related mortality in Brazil from 2001 to 2021.

Methods: An epidemiological study with a spatial analysis approach. Death data were obtained from the Mortality Information System (SIM/DATASUS) and population data from the Brazilian Institute of Geography and Statistics (IBGE) to calculate mortality rates. The epidemiological profile was described according to sex, age, race, marital status, education level, and municipality. Temporal trends were assessed using Joinpoint, and spatial analyses were performed using GeoDa.

Results: Over the study period, the highest mortality occurred among men (59%), infants under 1 year of age (17%), White individuals (49%), single individuals (39%), and those with 4 to 7 years of completed schooling (16%). Spatial analysis identified clusters of high mortality rates mainly in the Central-West and Southeast regions. The municipalities with the highest rates were Ipueiras (5.6 per 100,000), Muliterno (5.15 per 100,000), and Oliveira de Fátima (4.5 per 100,000). The average mortality rate was 0.56 per 100,000, peaking in 2001 (0.79 per 100,000) and reaching its lowest level in 2021 (0.27 per 100,000), with an average annual decrease of 4.38%.

Conclusion: Meningitis mortality decreased in Brazil. This study identified municipalities with high mortality rates and existing clusters, highlighting target populations and the need for targeted strategies.

RESUMO

Introdução: O Brasil apresenta padrões regionais heterogêneos de mortalidade por meningite. Entre 2001 e 2021, foram registrados 22.764 óbitos no país.

Objetivo: Analisar a distribuição espacial e o perfil epidemiológico da mortalidade por meningite no Brasil (2001–2021).

Métodos: Estudo epidemiológico com enfoque em análise espacial. Utilizaram-se dados de óbitos do SIM/DATASUS e dados populacionais do IBGE para cálculo de taxas de mortalidade. O perfil epidemiológico foi descrito por sexo, idade, raça, estado civil, escolaridade e município. A tendência temporal foi analisada no Joinpoint e a análise espacial no GeoDa.

Resultados: No período, a maior mortalidade ocorreu em homens (59%), menores de 1 ano (17%), brancos (49%), solteiros (39%) e com 4 a 7 anos de estudo (16%). Identificaram-se aglomerados de altas taxas nas regiões Centro-Oeste e Sudeste. Os municípios com maiores taxas foram Ipueiras (5,6/100 mil), Muliterno (5,15/100 mil) e Oliveira de Fátima (4,5/100 mil). A mortalidade média foi 0,56/100 mil, com maior valor em 2001 (0,79/100 mil) e menor em 2021 (0,27/100 mil), com redução média anual de 4,38%.

Conclusão: Houve diminuição da mortalidade por meningite no Brasil, com identificação de municípios e aglomerados prioritários, reforçando a necessidade de estratégias direcionadas.

Keywords: Spatio-Temporal Analysis. Mortality. Meningitis.

Palavras chave: Análise Espaço-Temporal. Mortalidade. Meningite.

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LN: Conceptualization; Methodology; Data curation; Formal analysis; Visualization; Writing – original draft; Writing – review & editing.

LMD: Formal analysis; Software; Visualization; Methodology; Writing – review & editing.

GF: Investigation; Data curation; Writing – review & editing.

TF: Software; Methodology; Writing – review & editing.

MCG, EKM, AVN, TCO, LDDFP, FRS: Investigation; Data curation; Writing – original draft; Writing – review & editing.

MFV: Methodology; Validation; Writing – review & editing.

ACG: Supervision; Conceptualization; Methodology; Project administration; Writing – review & editing.

INTRODUCTION

Meningitis is an inflammatory disease of the meninges, classified by ICD codes G00-G03, that remains an important cause of morbidity and mortality worldwide. In 2019, according to data from the Global Burden of Disease, global incidence was approximately 35.4 cases per 100,000 individuals, resulting in 236,000 deaths in that year, regardless of age.¹ Despite advances in vaccination and clinical management, the disease maintains high lethality, especially in bacterial variants, whose prognosis depends on early diagnosis and treatment.^{1,2,3,4}

In Brazil, meningitis requires immediate compulsory notification, which reflects its public health relevance and the need for continuous monitoring.⁵ Recent global strategies reinforce the goal of substantial reduction of meningitis mortality by 2030, while immunization programs have shown significant impact in reducing disease burden in different regions of the world.^{6,7} However, mortality remains associated with structural inequalities, including socioeconomic differences, heterogeneous vaccine coverage, and regional disparities in access to diagnosis and timely treatment.^{6,7,8}

Mortality distribution does not occur uniformly throughout the national territory. Brazil presents important demographic, economic, and healthcare contrasts among its regions, which can influence both the incidence and prognosis of the disease. Factors such as population density, urbanization, health system organization, and epidemiological surveillance capacity can impact the patterns observed over time and space.^{7,8,9,10}

Moreover, demographic changes, epidemiological transitions, and the introduction of new vaccination strategies over the last two decades may have altered the dynamics of meningitis mortality.^{6,7,8} Analysis of extensive temporal series allows the identification of trends, inflection points, and possible impact of public policies, while the spatial approach enables recognition of higher-risk areas and geographic clusters.

Given the persistence of meningitis as a public health issue and the possible regional heterogeneities, it becomes essential to analyze its spatiotemporal dynamics. Investigation of meningitis mortality in Brazil between 2001 and 2021 allows understanding of temporal trends, identification of spatial patterns, and provides a foundation for more targeted and equitable surveillance and control strategies.

METHODS

This is an epidemiological study analyzing secondary health data with a focus on spatiotemporal analysis. Data regarding meningitis death cases were obtained from the Mortality Information System (in Portuguese: *Sistema de Informação sobre Mortalidade*; SIM), of the Department of Informatics of the Brazilian

Unified Health System (in Portuguese: *Departamento de Informática do Sistema Único de Saúde*; DATASUS), via Tabnet, through place of death and place of occurrence. Population data used as denominators for calculating mortality rates were sourced from DATASUS.

For the analysis of meningitis mortality trends in Brazil, the period from 2001 to 2021 was selected to enable better understanding of the outcome in this historical series. The study population consists of individuals selected according to data available in DATASUS for all ages who were registered with deaths caused by meningitis. The following variables were considered in the analysis: sex, age group, race/skin color, marital status, education level, deaths by place of residence, year of death, place of death, and place of occurrence.

For the underlying cause of these deaths, ICD codes G00 to G03 from the International Classification of Diseases, 10th revision (ICD-10) were adopted. Information on the epidemiological profile and frequency of deaths due to meningitis was compiled using Microsoft Excel for Microsoft 365 MSO software. Thus, nominal variables were analyzed using absolute frequency and percentage of occurrence in the study population. Annual mortality was calculated using the total number of deaths in Brazil as the numerator and the Brazilian population in that year as the denominator, with a reference rate of 100,000 inhabitants. Municipality-level mortality was calculated based on indirect standardization, using the average number of cases for the period divided by the average population between 2001 and 2021, multiplied by 100,000 inhabitants.

The annual percent change (APC) was estimated with a 95% confidence interval (95% CI), considering $p < 0.05$ as statistically significant. Temporal trend analysis was conducted using Joinpoint Regression Program software, version 5.0.2 (2023). Considering the 21-year time series (2001–2021), the Joinpoint model allowed testing up to the maximum recommended number of inflection points. However, no statistically significant joinpoints were identified, and the most parsimonious model (0 joinpoints) was selected, indicating a single temporal trend throughout the entire period analyzed. Subsequently, the spatial distribution of meningitis mortality was evaluated through mapping of municipal mortality rates in Brazil. To reduce rate instability in areas with small populations, crude municipal values were smoothed using the local empirical Bayesian method, which weights each municipality's rate considering the rates of neighboring municipalities, based on a spatial proximity matrix. Spatial analyses and the construction of thematic maps were performed using GeoDa software, version 1.22.0.4 (2023).

To identify spatial clusters, the Global and Local Moran's Indices were used. The Global Moran's Index measures the correlation between first-order neighbors and was used to test the spatial dependence hypothesis. The method identifies spatial autocorrelation and can range from -1 to $+1$, where values close to zero indicate absence

of spatial dependence, with $p < 0.05$ considered significant. If the spatial dependence hypothesis is accepted, the Local Moran's Index (LISA, Local Index of Spatial Association) is used to observe the presence of spatial clusters, given $p < 0.05$. The results of the analyses described above were demonstrated using the Moran Map and LISA Map. The Moran Map graphically demonstrates the degree of similarity between neighbors, represented by four quadrants:

1. High-High (upper right quadrant): corresponds to municipalities with high mortality rates that are adjacent to municipalities that also have high mortality rates;
2. Low-Low (lower left quadrant): corresponds to municipalities with low mortality rates that are adjacent to municipalities that also have low mortality rates;
3. High-Low (lower right quadrant): corresponds to municipalities with high mortality rates that are adjacent to municipalities with low mortality rates;
4. Low-High (upper left quadrant): corresponds to municipalities with low mortality rates that are adjacent to municipalities with high mortality rates.

According to Resolution No. 510 of April 7, 2016, from the Brazilian National Health Council, there is no requirement for Research Ethics Committee review for studies that use publicly accessible information, as well as for research that employs secondary databases with aggregated information, without the possibility of individual identification of participants. In this context, the data used in this study were obtained from DATASUS, a public, freely accessible, and anonymized database that does not allow direct or indirect identification of individuals. Therefore, the present study is exempt from submission to the Research Ethics Committee, in accordance with the current legislation.

RESULTS

After analysis of the profile of Brazilian meningitis victims, a significant prevalence was identified among individuals under 1 year of age, totaling 17.13% of cases in the period. However, it is notable that the occurrence of this fatal event was partially comparable in distant age groups, with 12.66% of deaths occurring between 50 and 59 years, and 12.01% between 40 and 49 years of age. Additionally, there was a marked predominance of males, representing 59.13% of the analyzed cases. Similarly, the majority of victims were white (46.64%) and had single marital status (38.97%) (Table 1).

Regarding educational level, it was observed that the majority of deaths occurred among individuals with 4 to 7 years of completed education, comprising 16.25% of cases, followed by 13.66% among those with 1 to 3 years of completed education (Table 1). It is crucial to highlight that the majority of meningitis mortality cases occurred in

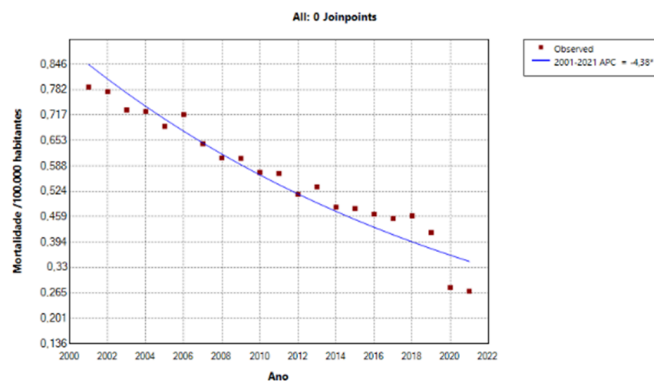
hospital settings, representing 93.05% of the total, followed by home settings at 2.69% (Table 1).

TABLE 1 – Epidemiological profile of individuals who died from meningitis in Brazil, between 2001-2021

Educational Level	n	%	Age Group	n	%
None	2554	11.22%	1 to 4 years	1831	8.04%
1 to 3 years	3110	13.66%	5 to 9 years	910	4.00%
4 to 7 years	3699	16.25%	10 to 14 years	856	3.76%
8 to 11 years	2672	11.74%	15 to 19 years	945	4.15%
12 years and more	836	3.67%	20 to 29 years	1793	7.88%
Ignored	9893	43.46%	30 to 39 years	2228	9.79%
Marital Status	n	%	40 to 49 years	2735	12.01%
Single	8870	38.97%	50 to 59 years	2882	12.66%
Married	5350	23.50%	60 to 69 years	2284	10.03%
Widowed	1430	6.28%	70 to 79 years	1471	6.46%
Divorced	855	3.76%	80 years and more	847	3.72%
Other	351	1.54%	Ignored age	82	0.36%
Ignored	5908	25.95%	Gender	n	%
Place of Death	n	%	Male	13460	59.13%
Hospital	21183	93.05%	Female	9294	40.83%
Other health facility	611	2.68%	Ignored	10	0.04%
Home	612	2.69%	Race/skin color	n	%
Public street	127	0.56%	White	10617	46.64%
Other	194	0.85%	Black	1739	7.64%
Ignored	37	0.16%	Yellow	90	0.40%
Age Group	n	%	Brown	8222	36.12%
Less than 1 year	3900	17.13%	Indigenous	148	0.65%
			Ignored	1948	8.56%

Source: Department of Informatics of the Brazilian United Health System (2024).

From 2001 to 2021, 22,764 deaths from meningitis were recorded in Brazil. The average mortality rate for this period was 0.56 per 100,000 inhabitants, with the lowest mortality recorded in 2021 (0.27 per 100,000 inhabitants) and the highest in 2001 (0.79 per 100,000 inhabitants). Analysis of the temporal pattern of mortality from 2001 to 2021 showed a significant average decrease of 4.38% per year in the mortality rate per 100,000 inhabitants ($p < 0.05$) (Fig. 1). Pearson's correlation coefficient was -0.9503 with $p < 0.05$, indicating a significant and inversely proportional linear correlation; over the years, there was a significant reduction in the mortality rate.



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
 -- Test Statistic and P-value not available for the Empirical Quantile method.
 Final Selected Model: 1 Joinpoint.

Source: Authors (2026).

FIGURE 1 – Temporal pattern of meningitis mortality in Brazil, between 2001-2021

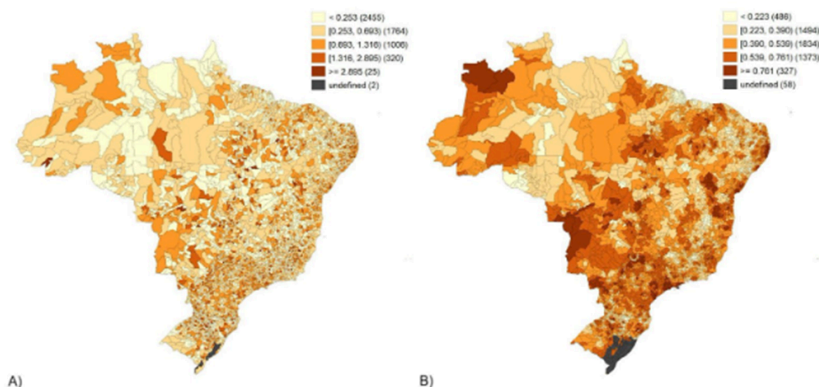


FIGURE 2 – Spatial analysis of meningitis mortality rate in Brazil, between 2001-2021
 A) Spatial analysis of the crude meningitis mortality rate in Brazil, between 2001-2021;
 B) Spatial analysis of the smoothed meningitis mortality rate in Brazil using the local empirical Bayesian method, between 2001-2021.
 Source: Authors (2026).

Application of LISA enabled identification of spatial clusters of both high-high and low-low values (Fig. 3A). The high-high pattern was identified mainly in the Central-West, Southeast, and North regions of Brazil, indicating similarity among municipalities in these regions for high mortality values from the analyzed pathology.

Meanwhile, the low-low pattern was identified mainly in the North, Northeast, and Southeast regions of Brazil, indicating similarity among municipalities in these regions for low mortality values from the analyzed pathology (Fig. 3A). Figure 3B demonstrates the degree of statistical significance of the clusters using the LISA Map.

DISCUSSION

This ecological analysis of national coverage shows persistent demographic and territorial heterogeneity in meningitis mortality in Brazil between 2001 and 2021. Mortality is concentrated disproportionately in male individuals, in those under one year of age, and in adults between 40 and 59 years. Although these distributions are largely consistent with national and global epidemiological patterns, their interpretation must be restricted to the population level, considering the ecological design and the use of secondary mortality data.

The predominance in males (59%) probably reflects the complex interaction between biological susceptibility, different exposure patterns, comorbidity burden, and dynamics of access to health services.¹² However, mortality differentials should not be interpreted exclusively as a behavioral phenomenon. Variations in diagnostic opportunities, referral pathways, and

Through spatial analysis, as shown in Figure 2A, there is a spatial dispersion of crude incidence of meningitis mortality in Brazil, presenting focus of incidence in the central-west and southeast regions. Ipueiras (5.6 per 100,000 inhabitants), Muliterno (5.15 per 100,000 inhabitants), Oliveira de Fátima (4.5 per 100,000 inhabitants), Lourdes (4.35 per 100,000 inhabitants), and Ribeirão Corrente (4.3 per 100,000 inhabitants) were the five municipalities that presented with the highest meningitis mortality rates between 2001 and 2021.

With smoothing of crude rates using the local empirical Bayesian method (Fig. 2B), it is possible to observe a more apparent spatial pattern, with aggregation of municipalities with higher mortality rates in the Central-West, Southeast, and North regions of Brazil. Spatial autocorrelation was identified using the Global Moran’s Index ($I=0.663$; $p=0.01$), demonstrating evidence of positive autocorrelation.

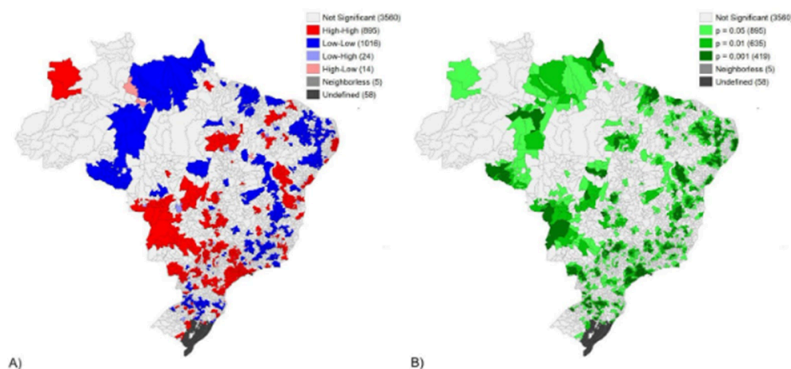


FIGURE 3 – Spatial clusters of meningitis mortality in Brazil, between 2001-2021
 A) Spatial clusters of meningitis mortality in Brazil using LISA, between 2001-2021;
 B) Degree of statistical significance of spatial clusters of meningitis mortality in Brazil, between 2001-2021.
 Source: Authors (2026).

certification practices for the underlying causes of death may also contribute to disparities registered between sexes. Therefore, the observed excess male mortality should be understood as a systemic and structural pattern, and not as an isolated effect of individual behavior.

Infant mortality remains a central characteristic of meningitis mortality. Beyond the immunological vulnerability inherent to this age group, mortality trends are strongly influenced by programmatic factors, such as vaccination opportunities, primary health care coverage, and the capacity for early recognition of serious infections.^{13,14} Thus, the high mortality in those under one year of age should be analyzed in context of health system responsiveness and the underlying social conditions.

The relative contribution of deaths among adults between 40 and 59 years requires cautious interpretation. In this age group, chronic conditions, immunosuppression states, and delay in diagnosis can increase lethality. However, ICD code aggregation G00-G03 prevents

etiological differentiation, limiting the ability to distinguish increased incidence and higher lethality. Thus, the observed pattern may reflect differences in clinical severity, diagnostic confirmation, or death certification practices, and not necessarily changes in transmission dynamics.

Findings related to race/skin color demand rigorous contextualization. Although the largest proportion of deaths was seen among white individuals (46.6%), this distribution partially follows the national demographic composition and may be influenced by regional variations in data completeness. Structural inequalities regarding access to health systems and differences in information quality can affect death registration in racialized populations.^{15,16} Therefore, the results should be interpreted as the registered distribution in the information system, and not as definitive evidence of difference in biological risk.

Lower educational level was associated with higher mortality, consistent with the role of socioeconomic position in determining health outcomes.¹⁶ Educational level, frequently used as a proxy for social vulnerability, may influence early symptom recognition and timely access to care.¹⁷ However, this variable is also subject to incompleteness and possible misclassification in information systems. Therefore, although findings point to social inequality as a relevant determinant, the magnitude of this association should be interpreted with caution.

The predominance of hospital deaths (93%) indicates that most fatal cases reached health services. However, hospital occurrence does not necessarily imply timely access or homogeneous health care quality. Delays in referrals, regional disparities in diagnostic capacity, and differences in intensive care availability may influence hospital lethality. Thus, hospital mortality should be understood as a marker of severity within the health system, and not as a direct indicator of uniform care performance.

Spatial analysis identified high-high clusters in Center-West, Southeast, and North regions. These clusters probably reflect territorial heterogeneity in mortality risk; however, they may result from the overlap of multiple mechanisms, including demographic structure, surveillance capacity, health infrastructure, and local socioeconomic conditions. Similarly, low-low clusters may indicate both lower actual risk and underdiagnosis or nonspecific classification of the underlying cause, especially in municipalities with lower technical capacity.^{18,19} In the absence of additional contextual indicators, causal inferences about spatial patterns should be made with caution.

The temporal variation observed over the two decades probably results from the interaction between demographic transitions, expansion of vaccination programs, improvement of information systems, and persistence of regional inequalities. The use of intercensal population estimates may have influenced rate calculation,

particularly in small municipalities. Although Bayesian smoothing reduces random fluctuations, it does not eliminate systematic biases.

This study presents limitations inherent to the use of secondary mortality data, including underreporting, variability in variable completeness, possible coding errors, and analysis restricted to the underlying cause of death. The ecological study design prevents individual-level inferences and is subject to ecological fallacy. Furthermore, the absence of etiological stratification limits specific interpretation by causal agent. Despite these restrictions, the analysis offers a comprehensive assessment of national meningitis mortality patterns over two decades, revealing persistent demographic and territorial inequalities that demand targeted public health responses.

CONCLUSION

Thus, the spatiotemporal analysis made it possible to identify municipalities with high meningitis mortality and highlighted important differences in mortality rates across locations. These findings reinforce the need for strategies tailored to local realities and specificities. This study provides scientific support for the organization and planning of actions aimed at strengthening healthcare in the most vulnerable areas, especially Primary Health Care, to expand access, improve care, promote health, and prevent meningitis-related adverse outcomes.

REFERENCES

1. GBD 2019 Meningitis Antimicrobial Resistance Collaborators. Global, regional, and national burden of meningitis and its aetiologies, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet Neurol.* 2023;22(8):685–711. doi: 10.1016/S1474-4422(23)00195-3
2. Rua R, McGavern DB. Advances in meningeal immunity. *Trends Mol Med.* 2018;24(6):542–59. doi: 10.1016/j.molmed.2018.04.003
3. Oordt-Speets AM, Bolijn R, van Hoorn RC, Bhavsar A, Kyaw MH. Global etiology of bacterial meningitis: A systematic review and meta-analysis. *PLoS One.* 2018;13(6):e0198772. doi: 10.1371/journal.pone.0198772
4. Thakur KT, Wilson MR. Chronic meningitis. *Continuum (Minneapolis, Minn).* 2018;24(5, Neuroinfectious Disease):1298–326. doi: 10.1212/CON.0000000000000664
5. Brasil. Ministério da Saúde. Portaria GM/MS nº 10.175, de 23 de janeiro de 2026. Altera a Lista Nacional de Notificação Compulsória de doenças, agravos e eventos de saúde pública, incluindo os critérios de notificação imediata no Sistema Único de Saúde. *Diário Oficial da União.* 2026.
6. Venkatesan P. Defeating meningitis by 2030: the WHO roadmap. *Lancet Infect Dis.* 2021;21(12):1635. doi: 10.1016/S1473-3099(21)00712-X
7. Borrow R, Caugant DA, Clark SA, Dinleyici EÇ, Hall I, Harrison LH, et al. Current global trends in meningococcal disease control, risk groups and vaccination: Consensus of the Global Meningococcal Initiative. *J Infect.* 2025;91(5):106635. doi: 10.1016/j.jinf.2025.106635
8. Silva LR da, Arruda LES de, Barreto I de JB, Aragão JVR de, Silva MLFI da, Lira G, et al. Geography and public health: analysis of the epidemiological dynamics of meningitis in Brazil, between 2010 and 2019. *Rev Bras Epidemiol.* 2024;27:e240031. doi: 10.1590/1980-549720240031

9. Silva AFT da, Valente F de S, Sousa LD de, Cardoso PNM, Silva MA da, Santos DR dos. Estudo epidemiológico sobre meningite bacteriana no Brasil no período entre 2009 a 2018. *Rev Med.* 2021;100(3):220–8. doi: 10.11606/issn.1679-9836.v100i3p220-228
10. Oliveira AV de, Rocha GB, Sampaio ALN, Rabelo ALP. Trends in incidence, mortality, and lethality due to meningitis in children and teenagers in Brazil: a nationwide time-series study from 2002 to 2022. *Rev Bras Epidemiol.* 2025;28(e250047):e250047. doi: 10.1590/1980-549720250047
11. Biswas A, Harbin S, Irvin E, Johnston H, Begum M, Tiong M, et al. Sex and Gender Differences in Occupational Hazard Exposures: a Scoping Review of the Recent Literature. *Curr Environ Health Rep [Internet].* 2021 Dec;8(4):267-280. doi: 10.1007/s40572-021-00330-8
12. Presa J, Serra L, Weil-Olivier C, York L. Preventing invasive meningococcal disease in early infancy. *Hum Vaccin Immunother [Internet].* 2022 Nov 30;18(5):1979846. doi: 10.1080/21645515.2021
13. Iori VCSS, Silva LL, Ribeiro e Silva MA, de Oliveira PMP, Garcia LB, Borges HHS; ANÁLISE EPIDEMIOLÓGICA DA EVOLUÇÃO HOSPITALAR DE PACIENTES COM MENINGITE NO ESTADO DE MATO GROSSO NO PERÍODO DE 2019 A 2023. *Univag.com.br [Internet].* 2019 Oct 31.
14. Chor D, Risso C. Aspectos epidemiológicos das desigualdades raciais em saúde no Brasil [Epidemiologic aspects of racial inequalities in health in Brazil]. *Cad. Saúde Pública [Internet].* 2005 Oct;21:1586–94. doi: 10.1590/S0102-311X2005000500033
15. de Castro BF, Rodrigues GS, da Silva AMB, Cassol APN, Minasse CY; ESTUDO EPIDEMIOLÓGICO: PREVALÊNCIA DA MENINGITE VIRAL NO BRASIL ENTRE 2019 E 2023. *Univag.com.br [Internet].* 2019 Oct 31.
16. Macedo LE, Ferreira VM, Feitosa CA, Nunes AMPB, Campos LC, Sáfiadi MAP. Impact of meningococcal C conjugate vaccination programs with and without catch-up campaigns in adolescents: lessons learned from Bahia, Brazil. *Hum Vaccin Immunother.* 2018;14(5):1131-7. doi: 10.1080/21645515.2017.1415682
17. Banhatto GM de SL, Costa HLS, Branco FDC, Paula G de S e, Perardt J, Barbosa E da S. Análise epidemiológica da meningite no nordeste brasileiro, de 2013 a 2022. *Cuad Ed Desar [Internet].* 2024 Jan 10;16(2 Edição Especial). doi: 10.55905/cuadv16n2-ed.esp.018
18. Aguiar TS, Fonseca MC, Santos MC dos, Nicoletti GP, Alcoforado DSG, Santos SCD dos, et al. Perfil epidemiológico da meningite no Brasil, com base nos dados provenientes do DataSUS nos anos de 2020 e 2021. *RSD [Internet].* 2022 Mar 3;11(3):e50811327016. doi: 10.33448/rsd-v11i3.27016
19. de Moraes JC, Barata RB. A doença meningocócica em São Paulo, Brasil, no século XX: características epidemiológicas. *Cad. Saúde Pública [Internet].* 2005 Oct 1;21(5):1458–71. doi: 10.1590/S0102-311X2005000500019