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RESEARCH

# COVID-19 TRENDS AMONG PREGNANT WOMEN IN BRAZIL AND THEIR RELATIONSHIP WITH HUMAN DEVELOPMENT AND THE GINI INDEX

*A TENDÊNCIA DA COVID-19 EM GESTANTES NO BRASIL E A RELAÇÃO COM DESENVOLVIMENTO HUMANO E ÍNDICE DE GINI*

*LA TENDENCIA DE LA COVID-19 EN GESTANTES EN BRASIL Y LA RELACIÓN CON EL DESARROLLO HUMANO Y ÍNDICE DE GINI*

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## ABSTRACT

**Objective:** to analyze trends in the incidence of COVID-19 among pregnant women during the pandemic and to assess its association with the Human Development Index (HDI) and the Gini Index. **Method:** this ecological study covered Brazil's 27 federal units and examined COVID-19 cases among pregnant women between 2020 and 2023. We obtained data from the Brazilian Institute of Geography and Statistics website and the OpenDataSUS platform. We analyzed trends using the join-point model and assessed associations using Poisson regression. **Results:** in the North region, in 2023, each 0.10 increase in the HDI was associated with an increase in the incidence of the disease (rate ratio [RR] = 595.035; $p < 0.001$), while in the South region, a decrease was observed (RR = 0.0002; $p < 0.001$). The highest Gini index, observed in the Northeast in 2021, was associated with an increase in incidence (RR = 11.579; $p < 0.001$), whereas in the Southeast and South regions, a negative association was found, with rate ratios ranging from 0.196 to 0.731 over the period ($p < 0.001$). **Conclusion:** the incidence of COVID-19 among pregnant women and its association with the HDI and the Gini Index varied across the study period and among the regions analyzed, reflecting the influence of socioeconomic inequalities on disease spread.

**Keywords:** COVID-19; Pregnancy; Pregnant People; Epidemiology; Incidence; Economic Indexes; Development Indicators; Health Statistics.

## RESUMO

***Objetivo***: *analisar a tendência da incidência de COVID-19 em gestantes durante a pandemia e avaliar sua associação com o índice de desenvolvimento humano (IDH) e o Índice de Gini.* ***Método:*** *trata-se de um estudo ecológico, abrangendo as 27 unidades federativas do Brasil, que considerou os casos de COVID-19 em gestantes entre 2020 e 2023. Os dados foram obtidos no site do Instituto Brasileiro de Geografia e Estatística e na plataforma Opendatasus. A tendência foi analisada por meio do modelo de joinpoint, e a associação, por meio da regressão de Poisson.* ***Resultados:*** *na região Norte, em 2023, cada incremento de 0,10 no IDH esteve associado ao aumento da incidência da doença (razão de taxas (RT) = 595,035; p < 0,001), enquanto na região Sul observou-se redução (RT = 0,0002; p < 0,001). O maior Índice de Gini, observado no Nordeste em 2021, associou-se ao aumento da incidência (RT = 11,579; p < 0,001), enquanto nas regiões Sudeste e Sul verificou-se associação negativa, com razões de taxas variando entre 0,196 e 0,731 ao longo do período (p < 0,001).* ***Conclusão:*** *a incidência de COVID-19 em gestantes e sua associação com o IDH e o Índice de Gini apresentaram-se de forma heterogênea ao longo do período e entre as regiões analisadas, refletindo a influência das desigualdades socioeconômicas na disseminação da doença*

***Palavras-chave****: COVID-19; Gravidez; Gestantes; Epidemiologia; Incidência; Indicadores Econômicos; Indicadores de Desenvolvimento; Estatísticas de Saúde.*

## RESUMEN

***Objective****: analizar la tendencia de la incidencia de COVID-19 en gestantes durante la pandemia y evaluar su asociación con el índice de desarrollo humano (IDH) y el Índice de Gini.* ***Método:*** *estudio ecológico que abarcó las 27 unidades federativas de Brasil y consideró los casos de COVID-19 en gestantes entre 2020 y 2023. Los datos se obtuvieron del sitio web del Instituto Brasileño de Geografía y Estadística y de la plataforma Opendatasus; la tendencia se analizó mediante el modelo de joinpoint, y la asociación, mediante la regresión de Poisson.* ***Resultados:*** *en la región Norte, en 2023, cada incremento de 0,10 en el IDH se asoció con el aumento de la incidencia de la enfermedad (razón de tasas [RT] = 595,035; p < 0,001), mientras que en la región Sur se observó una reducción (RT = 0,0002; p < 0,001). Por otro lado, un mayor Índice de Gini en la región Nordeste, en 2021, se asoció con un aumento de la incidencia (RT = 11,579; p < 0,001), mientras que en las regiones Sudeste y Sur se observó una asociación negativa, con razones de tasas entre 0,196 y 0,731 a lo largo del período (p < 0,001).* ***Conclusión:*** *la incidencia de COVID-19 en gestantes y su asociación con el IDH y el Índice de Gini fue heterogénea a lo largo del período y entre las regiones analizadas, lo que refleja la influencia de las desigualdades socioeconómicas en la propagación de la enfermedad.*

***Palabras clave:*** *COVID-19; Embarazo; Personas Embarazadas; Epidemiología; Incidencia; Indicadores Económicos; Indicadores de Desarrollo; Estadísticas de Salud.*

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## INTRODUTION

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, has emerged as one of the greatest public health challenges of the modern era, highlighting the vulnerability of certain population groups to severe forms of the disease. Among these groups, pregnant women are particularly at risk due to the physiological, immunological, and anatomical changes inherent to pregnancy. These changes increase susceptibility to respiratory infections and, consequently, the risk of serious complications, such as preterm birth, emergency cesarean section, and postpartum hemorrhage[1–3].

In 2020, there was a 40% increase in maternal deaths compared to previous years, followed by a further 14% rise, even after accounting for the overall increase in deaths attributed to the pandemic[4]. The predominant circulation of the Gamma variant in 2021 further exacerbated this situation, especially among unvaccinated pregnant women, resulting in a maternal mortality rate of 15.4%[5]. As of August 2023, more than 24,000 cases of severe acute respiratory syndrome due to COVID-19 had been reported among pregnant and postpartum women in Brazil, of whom 23.7% required admission to intensive care units (ICUs) and 8.4% died[6].

Beyond individual vulnerabilities, contextual and structural factors significantly influenced maternal outcomes during the pandemic. In low- and middle-income countries, pregnant women had up to an eightfold higher risk of death from COVID-19 compared to those living in high-income countries[7]. This disparity reflects inequalities in access to health services, limited hospital infrastructure, reduced availability of quality obstetric care, and heterogeneous government responses to the health crisis[8].

In this context, socioeconomic indicators such as the Human Development Index (HDI) and the Gini Index are relevant tools for understanding the unequal capacity of different regions to cope with the pandemic. The HDI measures socioeconomic development based on per capita income, educational attainment, and life expectancy, with higher values associated with better living conditions and greater access to essential services, such as health care and education[2]. In contrast, the Gini Index quantifies inequality in income distribution, with higher values indicating greater social inequality[9], which may reflect barriers to health care access and timely management of COVID-19 cases.

Although previous studies have examined the relationship between socioeconomic indicators and COVID-19 incidence in the general population[4,9], the literature still lacks analyses of the association between the HDI, the Gini Index, and disease incidence specifically among pregnant women. This gap is particularly relevant in the Brazilian context, which is characterized by profound social and regional inequalities that directly affect access to health services and maternal outcomes during public health emergencies[8].

Given the role of social determinants of health in shaping risk and vulnerability, we hypothesize that regions with lower HDI and greater income inequality (higher Gini Index) have a higher incidence of COVID-19 among pregnant women. Therefore, this study aims to analyze trends in COVID-19 incidence among pregnant women during the pandemic and assess its association with HDI and the Gini Index.

## METHOD

This analytical ecological study was conducted in Brazil. We extracted data by state and aggregated them by geographic region for comparative analysis. We collected information on reported cases of COVID-19 in pregnant women from February 2020 to December 2023 from the official OpenDataSUS website, available on the federal government's platform. All reported cases in pregnant women were selected from the database and filtered to include only those with a final diagnosis of COVID-19. Next, cases of pregnant women with COVID-19 aged 10 to 50 years were selected. The final sample consisted of cases with complete records for age, race/ethnicity, and disease confirmation; cases not confirmed for COVID-19 were excluded.

This study used the following independent variables: population, age, race/color, Gini Index, and HDI. Gini Index data were obtained from the official website of the Brazilian Institute of Geography and Statistics (https://www.ibge.gov.br/), based on the Continuous National Household Sample Survey (2020–2023). Information on the HDI was also collected from the Institute's official website and was available for the years 2020 and 2021. Because no data were released for 2022 and 2023, we used values from the most recent available period for subsequent analyses. We obtained data on the dependent variable (i.e., disease incidence) from the official website of the Ministry of Health, the OpenDataSUS Portal (https://opendatasus.saude.gov.br/).

Monthly estimates of the pregnant population were unavailable for calculating the COVID-19 incidence rate. Therefore, we obtained the denominator through an indirect approximation: for each month analyzed, we estimated the number of pregnant women based on the sum of live births registered in the 10 months following the reference month, according to data from SINASC/DATASUS. This procedure assumes that pregnancies resulting in live births during the subsequent period were ongoing during the month analyzed. Thus, using live birth records to estimate ongoing pregnancies is grounded in the average duration of pregnancy, allowing an approximate reconstruction of the number of pregnant women during a given period. Additionally, to account for pregnancy losses (spontaneous abortions, early losses, and other terminations), a correction factor was applied, adding 10% to this total[10,11].

The incidence rate was expressed as the number of new COVID-19 cases divided by the estimated total number of pregnant women in the corresponding month. We estimated COVID-19 incidence rates per 100,000 pregnant women, using monthly cases as the numerator. For annual rates, we estimated the pregnant-woman population based on the total number of live births registered in the year, increased by 10% to account for pregnancies that did not result in a live birth. This procedure assumes that the annual number of live births reasonably approximates the total number of annual pregnancies, given the average gestational duration of nine months and the relative stability of reproductive patterns during the study period. Equations 1 and 2 were used for these estimations:

The outcome variable was modeled based on the number of confirmed cases of COVID-19 in pregnant women and was considered a discrete quantitative variable. To analyze the relationship between the indicators

1. **Monthly incidence rate per 100,000 pregnant women:**
(Number of COVID cases-19 in the month)/
(Estimated pregnant population in the month)×100,000

2. **Annual incidence rate per 100,000 pregnant women:**
(Number of COVID cases-19 in the year)/
(Estimated pregnant population in the year)×100,000

of interest and the incidence rate, we employed a Poisson regression model with a log-link function. We chose this because the outcome is derived from case counts and modeled directly as the number of events, with an offset term equal to the logarithm of the population divided by 100,000, standardizing the rate per 100,000 inhabitants. Analyses were conducted using data from Brazil's 27 states over the four years evaluated (2020–2023), totaling 108 observations per model. Although the analysis spans four annual periods, the covariates (HDI and Gini Index) show sufficient spatial variability across states, enabling stable effect estimates, particularly in analyses involving interactions by region and year. Based on the model estimates, we obtained rate ratios (RR) for the HDI and the Gini Index, allowing quantification of the magnitude and direction of the associations between these socioeconomic indicators and COVID-19 incidence in pregnant women. All confidence intervals for incidence and mortality rates were calculated using a Poisson distribution.

Changes were analyzed in monthly incidence rates between 2020 and 2023 using a Joinpoint regression model, which identifies points of trend change over time. Using Poisson regression, we estimated the change-point locations and regression coefficients and selected the optimal number of joinpoints using a Monte Carlo permutation test, with a maximum of seven points. For each segment, monthly percentage changes (MPC) and their respective 95% confidence intervals were calculated, with trends classified as increase, decrease, or stability. Data were analyzed using Joinpoint Regression (v. 4.9.1.0). A significance level of 5% was adopted in all analyses.

This study employed publicly available secondary data and is therefore exempt from review by the Research Ethics Committee, in accordance with Resolution 738/2024 of the National Health Council.

## RESULTS

In Brazil, 1,113,745 cases of COVID-19 were reported among pregnant women from 2020 to 2023; 71.3% (793,965) were concentrated in the 20–34-year age group, and the mean age was 28.4 years (Table 1). Regarding race/ethnicity over the combined period from 2020 to 2023, 42.1% (468,509) were mixed-race, 36.9% (410,616) were white, and 5.2% were Black. Together, Black and mixed-race individuals accounted for 47.3% of cases (526,355), followed by white/Asian/Indigenous individuals, totaling 41% (457,022). Additionally, 36.4% (405,320) of cases were reported in the Southeastern region, 26.4% (294,433) in the Northeast, 22.6% (251,752) in the South, 7.5% (83,756) in the North, and 7.0% (78,484) in the Midwest.

COVID-19 incidence rates among pregnant women in Brazil varied significantly over time and across regions from 2020 to 2023. The incidence rate increased markedly from 5,203.47 cases per 100,000 pregnant women in 2020 to 13,852 in 2022, before declining to 5,817.92 in 2023. The South reported the highest incidence rates,

Table 1 — Characteristics of COVID-19 cases in pregnant women. Brazil, 2024

| Period | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|
| Number of cases | 156,269 | 404,717 | 390,361 | 162,398 |
| Age | | | | |
| Mean (standard deviation) | 29.7 (6.71) | 28.6 (6.70) | 28.1 (6.69) | 27.5 (6.72) |
| Median [min; max] | 29.0 [9.00; 50.0] | 28.0 [9.00; 50.0] | 28.0 [9.00; 50.0] | 27.0 [9.00; 50.0] |
| Age group (years) | | | | |
| 9–19 | 7,718 (4.9%) | 30,760 (7.6%) | 36,004 (9.2%) | 18,892 (11.6%) |
| 20–34 | 108,607 (69.5%) | 28,9406 (71.5%) | 279,833 (71.7%) | 11,6119 (71.5%) |
| 35–50 | 39,944 (25.6%) | 84,551 (20.9%) | 74,524 (19.1%) | 27,387 (16.9%) |
| Race/ethnicity | | | | |
| Asian | 11,984 (7.7%) | 4,551 (1.1%) | 12,258 (3.1%) | 10,214 (6.3%) |
| White | 59,445 (38.0%) | 143,256 (35.4%) | 147,962 (37.9%) | 59,953 (36.9%) |
| Indigenous | 2,184 (1.4%) | 2,422 (0.6%) | 1,963 (0.5%) | 830 (0.5%) |
| Mixed-race | 57,992 (37.1%) | 181,146 (44.8%) | 162,489 (41.6%) | 66,882 (41.2%) |
| Black | 8,287 (5.3%) | 21,090 (5.2%) | 19,658 (5.0%) | 8,811 (5.4%) |
| Race/ethnicity (grouped) | | | | |
| White/Asian/Native American | 73,613 (47.1%) | 150,229 (37.1%) | 162,183 (41.5%) | 70,997 (43.7%) |
| Black/Brown | 66,279 (42.4%) | 202,236 (50.0%) | 182,147 (46.7%) | 75,693 (46.6%) |
| Region | | | | |
| Midwest | 11,707 (7.5%) | 26,126 (6.5%) | 29,175 (7.5%) | 11,476 (7.1%) |
| Northeast | 43,676 (27.9%) | 109,112 (27.0%) | 101,307 (26.0%) | 40,338 (24.8%) |
| North | 10,677 (6.8%) | 30,985 (7.7%) | 26,309 (6.7%) | 15,785 (9.7%) |
| Southeast | 66,071 (42.3%) | 150,424 (37.2%) | 13,4978 (34.6%) | 53,847 (33.2%) |
| South | 24,138 (15.4%) | 88,070 (21.8%) | 98,592 (25.3%) | 40,952 (25.2%) |

Source: Instituto Brasileiro de Geografia e Estatística/Departamento de Informática do Sistema Único de Saúde, 2024.

peaking in 2022 at 24,912 cases per 100,000, making it the most affected region during this period. Conversely, the North consistently demonstrated the lowest incidence rates, notably in 2020 with 3,217.89 cases per 100,000 (Table 2).

A significant increase in the incidence of COVID-19 cases among pregnant women in Brazil was observed during the initial months of the pandemic, particularly between January and July 2020. This period was characterized by high MPC values and statistical significance across most regions. On average, the incidence in Brazil increased 159.2% per month. The most pronounced monthly rises were reported in the Southeastern (173.2%), Midwestern (171.5%), and Northeastern (116.7%) regions (Table 3).

Between July 2020 and January 2022, most regions exhibited a trend of moderate growth in incidence, as reflected by MPC values ranging from 3% to 5%. Beginning in 2022, COVID-19 incidence rates among pregnant women changed significantly, with most regions showing a sustained reduction. In Brazil, the incidence rate decreased by an average of 6.5% per month between January 2022 and December 2023. In the Southern region, a significant, though less intense, increase compared to other regions was observed at the onset of the pandemic, from January 2020 to October 2020, with an average monthly increase of 61.4% in the incidence rate. In the subsequent period, from October 2020 to January 2022, the upward trend persisted but at a more moderate rate, with an average monthly increase of 5.0%. From January 2022 onward, the trend reversed, indicating a significant decline. Between January 2022 and April 2023, the rate exhibited an average monthly decrease of 4.2%, marking the onset of a consistent downward trend. This was followed by a more pronounced decrease, with a monthly variation of -18.8% from April to December 2023, which was the most substantial drop among all regions (Table 3).

Regarding the relationship between HDI and the incidence rate of COVID-19 among pregnant women in Brazil, we observed heterogeneity in both the direction and magnitude of associations over time and across regions. In Brazil in 2020, a 0.10-unit increase in the HDI was associated with an approximately 4.5-fold increase in disease incidence ($p < 0.001$). Among Brazilian regions, the North stood out in 2023 with the strongest positive association of the study period: for every 0.10-unit increase in the HDI, there was an approximately 595-fold increase in the incidence rate among pregnant women ($p < 0.001$). In contrast, the South in 2023 showed the strongest inverse association, with a RR of 0.0002, indicating a reduction in incidence as HDI increased ($p < 0.001$) (Table 4).

An analysis of the relationship between the Gini Index and the incidence rate of COVID-19 among pregnant women revealed significant regional and temporal variations from 2020 to 2023. The incidence rate increased markedly in 2021 (RR = 1.248) and 2023 (RR = 1.113), indicating that for every 0.10-unit increase in the Gini Index, the incidence rose by approximately 24.8% and 11.3%, respectively (Table 5).

In the regional analysis, the Northeast showed high RRs, increasing by approximately 11-fold in 2021, 10-fold in 2022, and 6.1-fold in 2023. The Northern region showed a positive and statistically significant association between the Gini Index and COVID-19 incidence among pregnant women in 2020, 2021, and 2023. Specifically, in 2020, each 0.10-unit increase in the Gini Index corresponded to a 22.4% increase in incidence. This increase was even more pronounced in 2021, reaching 66.7%, while in 2023 it was 7.0%.

Conversely, the Southeastern (beginning in 2021) and Southern regions exhibited an inverse association throughout the period, with RRs below 1. This finding indicates that increases in the Gini Index were associated with a reduction in the COVID-19 incidence rate among pregnant women. Notably, in the South, the RR shifted from 0.731 (a 26.9% reduction) in 2020 to 0.196 (an 80.4% reduction) in 2022 ($p < 0.001$) for incidence (Table 5).

All items included in the semantic evaluation were considered satisfactory by the target audience. The SAI of the video was 100% (Table 2). The participants did not provide any suggestions for modifications to the video.

## DISCUSSION

This study found that COVID-19 incidence among pregnant women in Brazil varied significantly over time and across regions, with a national peak in 2022 and a sharp decline in 2023. The South recorded the highest incidence rates during the study period, particularly in 2022, while the North had the lowest. Initially, incidence increased rapidly in this population group between 2020 and early 2022, followed by a decline across all regions. The HDI showed a positive association with incidence, especially in the Northern region in 2023, and the highest levels of inequality (Gini Index) were associated with increased incidence, particularly in Brazil and the Northeast in 2021.

Table 2 – Annual COVID-19 incidence rates per 100,000 pregnant women in Brazil and its major regions. Brazil, 2024

| Period | No. of cases | Incidence rate (95% CI) |
|---|---|---|
| Brazil | | |
| 2020 | 15,6269 | 5,203.47 (5,177.73; 5,229.33) |
| 2021 | 40,4717 | 1,3743 (13,701; 13,786) |
| 2022 | 39,0361 | 1,3852 (13,808; 13,895) |
| 2023 | 16,2398 | 5,817.92 (5,789.69; 5,846.29) |
| Midwest | | |
| 2020 | 11,707 | 4,617.73 (4,534.83; 4,702.14) |
| 2021 | 26,126 | 1,0371 (10,246; 10,498) |
| 2022 | 29,175 | 1,1823 (11,688; 11,960) |
| 2023 | 11,476 | 4,612.95 (4,529.32; 4,698.12) |
| Northeast | | |
| 2020 | 43,676 | 5,151.92 (5,103.83; 5,200.47) |
| 2021 | 10,9112 | 1,2948 (12,872; 13,025) |
| 2022 | 10,1307 | 1,2990 (12,910; 13,070) |
| 2023 | 40,338 | 5,212.99 (5,162.36; 5,264.11) |
| North | | |
| 2020 | 10,677 | 3,217.89 (3,157.43; 3,279.51) |
| 2021 | 30,985 | 9,105.17 (9,004.35; 9,207.12) |
| 2022 | 26,309 | 8,271.27 (8,171.92; 8,371.82) |
| 2023 | 15,785 | 5,049.25 (4,971.09; 5,128.63) |
| Southeast | | |
| 2020 | 66,071 | 5,707.39 (5,664.03; 5,751.07) |
| 2021 | 15,0424 | 1,3543 (13,475; 13,612) |
| 2022 | 13,4978 | 1,2525 (12,459; 12,592) |
| 2023 | 53,847 | 5,066.63 (5,024.02; 5,109.61) |
| South | | |
| 2020 | 24,138 | 5,852.4 (5,779.04; 5,926.7) |
| 2021 | 88,070 | 2,2061 (21,916; 22,207) |
| 2022 | 98,592 | 24,912 (24,757; 25,068) |
| 2023 | 40,952 | 10,410 (10,310; 10,512) |

Caption: 95% CI – 95% confidence interval.

Source: Instituto Brasileiro de Geografia e Estatística/Departamento de Informática do Sistema Único de Saúde, 2024.

Table 3 – Estimates of the temporal trend in COVID-19-specific incidence rates among pregnant women in Brazil's regions, from 2020 to 2023. Brazil, 2024

| Incidence (per 100,000 pregnant women) | Period | MPC (95% CI) | | AAPC (95% CI) | |
|---|---|---|---|---|---|
| 2 joint points | | | | | |
| | Jan 2020 to Jul 2020 | 159.2 (61.2; 1,376.1)* | ↑ | 11.1 (5.3; 26.7)* | |
| Brazil | Jul 2020 to Jan 2022 | 4.5 (2.1; 7.5)* | ↑ | | ↑ |
| | Jan 2022 to Dec 2023 | -6.5 (-9.3; -5.0)* | ↓ | | |
| | Mar 20 to Jul 20 | 171.5 (7.2; 1,160.1)* | ↑ | 7.5 (-0.1; 14.0) | |
| Midwest | Jul 2020 to Jan 2022 | 4.6 (4.1; 9.6) | – | | – |
| | Jan 2022 to Dec 2023 | -6.5 (-10.7; -4.2)* | ↓ | | |
| | Mar 20 to Jul 20 | 116.7 (24.1; 909.5)* | ↑ | 5.2 (1.0; 11.9)* | |
| Northeast | Jul 2020 to Jan 2022 | 4.1 (1.0; 7.3)* | ↑ | | ↑ |
| | Jan 2022 to Dec 2023 | -6.4 (-9.6; -4.7)* | ↓ | | |
| North | Jan 2020 to Jul 2020 | 104.9 (36.6; 632.6)* | ↑ | 8.7 (4.1; 21.6)* | |
| | Jul 2020 to Jan 2022 | 4.1 (2.1; 6.7)* | ↑ | | ↑ |
| | Jan 2022 to Dec 2023 | -4.7 (-6.8; -3.5)* | ↓ | | |
| Southeast | Jan 2020 to Jul 2020 | 173.2 (51.1; 3,142.3)* | ↑ | 11.2 (4.1; 32.2)* | |
| | Jul 2020 to Jan 2022 | 3.4 (0.4; 7.3)* | ↑ | | ↑ |
| | Jan 2022 to Dec 2023 | -6.9 (-11.3; -5.0)* | ↓ | | |
| 3 joint points | | | | | |
| | Jan 20 to Oct 20 | 61.4 (38.1; 157.4)* | ↑ | 6.0 (3.1; 13.1)* | |
| South | Oct 20 to Jan 22 | 5.0 (3.2; 8.1)* | ↑ | | |
| | Jan 2022 to Apr 2023 | -4.2 (-6.4; -2.1)* | ↓ | | ↑ |
| | Apr 23 to Dec 23 | -18.8 (-33.7; -12.9)* | ↓ | | |

Caption: *Changes – increase (↑), decrease (↓), or stability (–); AAPC – average annual percentage change; MPC – monthly percentage change; 95% CI – 95% confidence interval.

Source: Instituto Brasileiro de Geografia e Estatística/Departamento de Informática do Sistema Único de Saúde, 2024

In the context of COVID-19, it is important to note that pregnant women are considered more vulnerable to viral infection than non-pregnant women due to physiological and immunological changes, increased oxygen consumption, and decreased thoracic compliance, which can result in higher maternal and fetal morbidity and mortality[1].

Most cases of COVID-19 in pregnant women are mild, although approximately 15% may progress to severe disease. Risk factors for severe disease are similar to those in the general population, notably advanced maternal age, obesity, hypertension, and pre-pregnancy diabetes[12]. Symptomatic COVID-19 infection is associated with an increased risk of preterm birth, whereas severe cases are linked to preeclampsia, preterm birth, cesarean delivery, gestational diabetes, ICU admission, mechanical ventilation, and low birth weight[13].

Another important factor in negative COVID-19 outcomes is race/skin color; in this study, a higher incidence of COVID-19 was observed among Black pregnant women. In Brazil, according to Law 12,288 of July 20, 2010, which established the Statute of Racial Equality, the Black population comprises people who self-identify as Black or Brown[14]. Notably, the Black population faced additional barriers during the pandemic, particularly regarding access to health care services, reflecting pre-existing structural inequalities. Greater occupational exposure to SARS-CoV-2 and difficulties in accessing care may have contributed to higher incidence, severity, and mortality from COVID-19 in the general population, particularly among pregnant women[15].

Regarding socioeconomic indicators, both the HDI and the Gini Index were positively associated with COVID-19 incidence among pregnant women in Brazilian regions.

Table 4 – Analysis of the relationship between the HDI and the COVID-19 incidence rate among pregnant women in Brazilian regions, from 2020 to 2023. Brazil, 2024

| Relationship between incidence rate and HDI | Year | Rate ratio | 95% CI | | p-value |
|---|---|---|---|---|---|
| Brazil | 2020 | 4.563 | 4.415 | 4.716 | <0.001 |
| Brazil | 2021 | 3.833 | 3.744 | 3.924 | <0.001 |
| Brazil | 2022 | NE | NE | NE | NE |
| Brazil | 2023 | 1.013 | 0.966 | 1.062 | 0.601 |
| Midwest | 2020 | 1.154 | 1.080 | 1.232 | <0.001 |
| Midwest | 2021 | 0.897 | 0.858 | 0.937 | <0.001 |
| Midwest | 2022 | 0.461 | 0.433 | 0.490 | <0.001 |
| Midwest | 2023 | 0.130 | 0.117 | 0.146 | <0.001 |
| Northeast | 2020 | 3.301 | 3.185 | 3.421 | <0.001 |
| Northeast | 2021 | 4.584 | 4.452 | 4.719 | <0.001 |
| Northeast | 2022 | 22.435 | 21.154 | 23.794 | <0.001 |
| Northeast | 2023 | 37.889 | 35.345 | 40.617 | <0.001 |
| North | 2020 | 11.656 | 10.233 | 13.279 | <0.001 |
| North | 2021 | 6.994 | 6.445 | 7.591 | <0.001 |
| North | 2022 | 19.175 | 17.648 | 20.834 | <0.001 |
| North | 2023 | 595.035 | 526.319 | 672.724 | <0.001 |
| Southeast | 2020 | 3.965 | 3.790 | 4.148 | <0.001 |
| Southeast | 2021 | 1.179 | 1.148 | 1.211 | <0.001 |
| Southeast | 2022 | 0.651 | 0.623 | 0.680 | <0.001 |
| Southeast | 2023 | 1.537 | 1.469 | 1.607 | <0.001 |
| South | 2020 | 11.244 | 10.684 | 11.834 | <0.001 |
| South | 2021 | 24.406 | 22.972 | 25.928 | <0.001 |
| South | 2022 | NE | NE | NE | NE |
| South | 2023 | 0.0002 | 0.0002 | 0.0003 | <0.001 |

Caption: HDI - Human Development Index in increments of 0.10; 95% CI - 95% confidence interval; NE - not estimated.
Source: Instituto Brasileiro de Geografia e Estatística/Departamento de Informática do Sistema Único de Saúde, 2024.

This finding is consistent with global studies indicating that regions with higher HDI values tend to have higher incidence rates of the disease[2]. This association can be explained by the structural characteristics of these regions, which generally have higher urban population density, greater population mobility, and better access to health services. These factors increase testing and case reporting, reflecting more effective epidemiological surveillance rather than necessarily indicating a higher risk of infection[2,9].

Similarly, the Gini Index, which measures income inequality, also showed a positive correlation with COVID-19 incidence among pregnant women. This relationship may suggest that, even in more developed regions, internal inequalities favor viral spread, particularly when vulnerable populations coexist with higher-income groups in contexts of unequal access to preventive measures and health care[9]. Therefore, the simultaneous presence of high levels of human development and economic inequality in some states may generate heterogeneous incidence patterns, highlighting that access to resources and services is not uniform and may be restricted for vulnerable groups, thereby increasing barriers to care, early testing, and timely treatment[2,9].

Although the HDI and the Gini Index represent different dimensions (i.e., socioeconomic development and income inequality, respectively), some Brazilian states simultaneously exhibit high values for both indicators. This coexistence reflects a development pattern marked by structural asymmetries, in which average progress in health, education, and income does not necessarily translate into equitable access to these resources for the population[16].

Tabela 5 – Relationship between the Gini Index and the COVID-19 incidence rate among pregnant women in Brazilian regions, from 2020 to 2023. Brazil, 2024

| Relationships between incidence rate and Gini index | Year | Rate ratio | 95% CI | | p-value |
|---|---|---|---|---|---|
| Brazil | 2020 | 1,041 | 1,018 | 1,063 | <0,001 |
| Brazil | 2021 | 1,248 | 1,231 | 1,266 | <0,001 |
| Brazil | 2022 | 1,051 | 1,034 | 1,068 | <0,001 |
| Brazil | 2023 | 1,113 | 1,086 | 1,141 | <0,001 |
| Midwest | 2020 | 1,099 | 1,046 | 1,154 | <0,001 |
| Midwest | 2021 | 1,390 | 1,349 | 1,433 | <0,001 |
| Midwest | 2022 | 1,403 | 1,354 | 1,454 | <0,001 |
| Midwest | 2023 | 1,317 | 1,243 | 1,396 | <0,001 |
| Northeast | 2020 | 0,883 | 0,854 | 0,912 | <0,001 |
| Northeast | 2021 | 11,579 | 11,239 | 11,930 | <0,001 |
| Northeast | 2022 | 10,651 | 10,317 | 10,996 | <0,001 |
| Northeast | 2023 | 6,122 | 5,808 | 6,452 | <0,001 |
| North | 2020 | 1,224 | 1,134 | 1,321 | <0,001 |
| North | 2021 | 1,667 | 1,594 | 1,744 | <0,001 |
| North | 2022 | 0,883 | 0,834 | 0,935 | <0,001 |
| North | 2023 | 1,070 | 0,991 | 1,156 | 0,086 |
| Southeast | 2020 | 1,407 | 1,372 | 1,444 | <0,001 |
| Southeast | 2021 | 0,569 | 0,558 | 0,580 | <0,001 |
| Southeast | 2022 | 0,495 | 0,484 | 0,506 | <0,001 |
| Southeast | 2023 | 0,581 | 0,560 | 0,602 | <0,001 |
| South | 2020 | 0,731 | 0,701 | 0,762 | <0,001 |
| South | 2021 | 0,198 | 0,193 | 0,204 | <0,001 |
| South | 2022 | 0,196 | 0,191 | 0,201 | <0,001 |
| South | 2023 | 0,341 | 0,328 | 0,355 | <0,001 |

Caption: Gini index (in increments of 0.10); 95% CI – 95% confidence interval.
Source: Instituto Brasileiro de Geografia e Estatística/Departamento de Informática do Sistema Único de Saúde, 2024

In this context, sociodemographic and economic differences among Brazilian regions may have affected pregnant women's access to health services during the critical phase of the pandemic, since more vulnerable pregnant women are at greater risk of negative COVID-19-related outcomes[8,17]. Nevertheless, health inequalities predate COVID-19, particularly regarding prenatal care. The proportion of women who received no prenatal care was 60% higher in the North than the national average, while the South had the highest coverage of women with at least six prenatal visits. Additionally, the Southeastern, Southern, and Central-Western regions had a higher prevalence of women who began prenatal care early[17].

During the pandemic in Brazil, social and regional inequalities in health service use showed that municipalities with fewer health resources and greater socioeconomic inequality had higher COVID-19 incidence rates among pregnant women[8]. The heterogeneity of Brazilian regions, evidenced by strain on the healthcare system and the social and economic impacts of the pandemic, also influenced variations in the COVID-19 incidence rate among pregnant women. Thus, the high incidence rates among pregnant women, as observed in this study in the Southeast, may be related to higher population density, greater population mobility, and an extensive network of laboratories and health services, as well as easier access to diagnostic tools, which are essential for case reporting[18].

Although Brazil has a relatively well-structured health care system, the Central-West, Southeast, and South stand out for greater availability of, and easier access to, health care services than other regions[19]. In contrast, the North and Northeast, which face greater vulnerabilities in healthcare provision, were the first to implement stricter restrictive measures to mitigate the impact on an already fragile system[20].

The incidence of COVID-19 among socially vulnerable populations thus reflects the decisive influence of socioeconomic factors on the dynamics of viral transmission. Social vulnerability extends beyond income status and includes a complex set of determinants, including informal employment, lower educational attainment, precarious housing conditions, limited access to health services, and higher population density in peripheral urban areas. These structural factors influence both exposure to the virus and the ability to adopt preventive measures, such as social distancing, proper mask use, and personal hygiene, making these populations particularly susceptible to community spread of SARS-CoV-2 during the critical phase of the pandemic[21,22].

Moreover, socioeconomic vulnerability exposed a considerable number of pregnant women to an increased risk of viral exposure during the critical phase of the pandemic, especially due to the nature of their occupations in the labor market. Dependence on income for subsistence reduced their ability to interrupt work activities, exposing these women to frequent travel and shared environments, which significantly increased their risk of infection[21,22].

It is also necessary to consider the quality of epidemiological data on COVID-19 across the country's different regions, especially given the collapse of healthcare services observed at various points during the pandemic. Northern Brazil experienced one of the country's most severe situations, marked by shortages of hospital and ICU beds, scarcity of essential supplies such as medical oxygen, and the need for interstate patient transfers. These factors directly affected morbidity and mortality and may also have compromised the consistency, completeness, and timeliness of health records[23,24].

In situations of extreme overload in health services, patient care may take priority over routine reporting procedures, which can affect data quality by region. A shortage of human resources, combined with a sudden increase in demand for hospitalizations due to COVID-19, may result in underreporting of cases, delays in recording outcomes, and incomplete reporting of relevant variables, such as comorbidities, gestational age, and obstetric conditions. Moreover, patient transfers between states can fragment clinical information, hindering case traceability and the consolidation of reliable data in official systems[23,24].

Another factor contributing to changes in COVID-19 incidence rates, in addition to the strain on health care systems, was the emergence of new variants of the virus. The Delta variant, which is considered more lethal, and the highly transmissible Omicron variant led to significant increases in incidence and mortality rates across different regions of Brazil[25]. At the same time, vaccination campaign dynamics also influenced these changes. The delay in launching the vaccination campaign, combined with unequal distribution of doses among regions, low vaccination coverage in high-risk populations, and the spread of misinformation about vaccine benefits and adverse effects (e.g., the federal government's anti-vaccination stance) contributed to the steep increase in incidence curves observed in the country[25].

Scientific evidence indicates that COVID-19 vaccination in pregnant women reduces the risk of severe infection, hospitalization, pregnancy complications, and maternal death[12]. However, vaccine hesitancy, particularly among pregnant women, has been observed globally. Hesitancy regarding the COVID-19 vaccine among pregnant women is complex and multifactorial, driven by concerns about rapid vaccine development and approval; doubts about the political figures overseeing vaccination programs; safety concerns for pregnant women and their fetuses; apprehension about potentially harmful ingredients; fear of congenital malformations; denial of COVID-19 severity; belief in conspiracy theories; and the perception that vaccines are unnecessary[26].

The literature indicates that the type of care provided during pregnancy can positively influence adherence to COVID-19 vaccination. Women who did not receive prenatal care exclusively in the public sector were more likely to forgo COVID-19 vaccination. Thus, receiving prenatal care in the public system was identified as a protective factor, possibly because healthcare professionals in these services work directly on the front lines of the fight against COVID-19 and provide guidance to pregnant women on the risks of viral infection and encourage adherence to the vaccination schedule[27].

Therefore, it is emphasized that the quality of prenatal healthcare may be influenced by the socioeconomic indicators of a given region, which play an important role in the health-disease process, particularly for pregnant women in Brazil in the context of infectious diseases such as COVID-19 and their adverse outcomes.

This study has limitations inherent to using secondary data, particularly regarding possible underreporting at the start of the pandemic, when diagnostic testing was limited and, in many contexts, restricted to moderate and severe cases, which may have underestimated mild or asymptomatic cases. Additionally, the analysis covered a long period encompassing different phases of the pandemic, during which variations in testing and public health policies across federal units may affect the temporal comparability of the data. Additionally, the analysis conducted in this study does not permit causal conclusions. Lastly, although IDH data were available only for 2020 and 2021 during the data collection period, with these values also applied to 2022 and 2023, the impact of this approximation on the results is likely minimal, as IDH varies gradually and cumulatively, and significant fluctuations over a short period are uncommon.

Nevertheless, this study offers a robust analytical approach to COVID-19 incidence among pregnant women in Brazil, covering a comprehensive timeframe and grounded in national secondary data. By expanding the evidence base regarding the pandemic's impacts on maternal health, the results provide essential quantitative parameters to guide future research and risk assessments in similar epidemiological contexts, thereby contributing to the advancement of scientific knowledge in this field.

## CONCLUSION

This study identified temporal and regional variations in COVID-19 incidence among pregnant women in Brazil, with a peak in 2021 and a significant decline in 2023. The Southern region had the highest incidence rates, while the Northern region recorded the lowest. A positive association between HDI and incidence suggests that, even in more developed areas, inequalities persist and negatively affect vulnerable populations. Additionally, high levels of social inequality, as measured by the Gini Index, correlated with higher incidence, particularly in Brazil in 2021 and in the Northeast in 2022.

Given that SARS-CoV-2 continues to circulate, this underscores the importance of improving epidemiological surveillance strategies and maternal health planning in Brazil. An analysis of COVID-19 incidence trends among pregnant women over four years, combined with socioeconomic indicators such as the HDI and Gini Index, highlights the need to incorporate social and racial determinants into public policy formulation.

Targeted, locally tailored actions are urgently needed for historically vulnerable populations. The study also emphasizes the importance of specific strategies to expand COVID-19 vaccination coverage among pregnant women, with the aim of reducing severe cases and preventable deaths. These findings can inform more effective interventions to address future public health emergencies and help mitigate inequalities in maternal health in the country. It is suggested that future studies analyze the characteristics of cases and deaths among pregnant women due to the disease and their relationship to COVID-19 vaccination status in the post-public health emergency period.

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