

ORIGINAL ARTICLE

Analysis of incidence, mortality and lethality by COVID-19 in the States of Pará and Rio Grande do Sul, Brazil: epidemiological aspects of evolution 2020-2022

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Abstract

Introduction: COVID-19 unfolded differently in Pará and Rio Grande do Sul, Brazil, owing to distinct socioeconomic contexts. From 2020 to 2022, both states implemented diverse measures against the virus SARS-CoV-2, including vaccination and variant monitoring, tailored to their specific challenges. Understanding regional impacts on COVID-19 indicators is crucial for designing effective control strategies.

Objective: to analyze the incidence, mortality, and lethality of COVID-19 in Pará and Rio Grande do Sul and the trends of these indicators from 2020 to 2022.

Methods: ecological study with time series from public and official data available in the Health Secretariat of Pará and Rio Grande do Sul, including all cases and deaths by COVID-19 from February 2020 to December 2022. Lethality, mortality, and incidence rates were calculated. Prais-Winsten regression analysis was used, and trends were classified as stationary, increasing, or decreasing. Significant differences were considered when the p-value is <0.05.

Results: when examining the lethality rates between the states of Para and Rio Grande do Sul, an observable trend emerged during the analyzed period. It became evident that the total lethality rate consistently remained higher in Para. Noteworthy peaks in lethality were mainly observed during the months of April 2020, May 2020, and March 2021. The incidence rates showed increasing trends during 2020, both in Pará with a daily percentage change (DPC) of 1.69% ($p < 0.05$) and in Rio Grande do Sul with a DPC of 1.70% ($p < 0.05$). In 2021, the incidence was decreasing ($p < 0.05$) in both states, with a DPC of 0.60% in Pará and 0.64% in Rio Grande do Sul and continued this trend in Pará in 2022 (DPC of -0.50% $p < 0.05$), becoming stationary in Rio Grande do Sul, with a non-significant p-value ($p > 0.05$).

Conclusion: the positive impact of the vaccination program is reflected in the evolution of the pandemic. During the study period Rio Grande do Sul and Para exhibited a stationary incidence trend, emphasizing the need for continued monitoring of cases and morbidity across various age and demographic groups.

Keywords: COVID-19, SARS-CoV-2, incidence, mortality, lethality, trends.

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Authors summary

Why was this study done?

When evaluating the COVID-19 scenario in the states of Pará and Rio Grande do Sul and its combat measures such as variants and vaccination in the period from 2020 to 2022. It is important to recognize that socioeconomic disparities between the north and south of the country differentiate the context. It is necessary to identify the factors that influenced the epidemiological indicators of COVID-19 and understand the pandemic situation in the different Brazilian states, in order to facilitate the formulation of strategies to control the disease. Analyzing the Infection Rate, Mortality and Fatality Rate in the States of Pará and Rio Grande do Sul and Observing the Trends of These Indicators During the Period from 2020 to 2022.

What did the researchers do and find?

When comparing the lethality between the states of Para and Rio Grande do Sul, it was noted that during the period analyzed, the total rate remained higher in the state of Pará, highlighting the months of April/2020, May/2020 and March/2021. Incidence rates showed increasing trends during 2020. In 2021, the incidence was decreasing in both states.

What do these findings mean?

The vaccination program has had a beneficial effect on the trajectory of the pandemic. Throughout the period examined, there was stability in the incidence of cases in both States, which suggests the importance of maintaining continuous surveillance over the number of cases and the health of different age groups and groups.

Highlights

Pará had higher fatality rates, but lower mortality rates compared to Rio Grande do Sul in 2020. Rio Grande do Sul has consistently presented higher incidence rates compared to Pará, with the difference increasing in 2021 and 2022. Mortality rates showed an increasing trend in Rio Grande do Sul in 2020 but remained stable in Pará. Both states saw decreasing trends in 2021 and 2022. Fatality rates showed decreasing trends in the first two years and remained stable in 2022 in Pará, while in RS they remained constant throughout the entire period analyzed.

INTRODUCTION

In Brazil, existing evidence primarily concentrates on individual states¹⁻⁶ or compares states within specific geographic regions⁷. However, there's a gap in research that directly compares states from different geographical areas. To address this and comprehensively monitor the evolving landscape of the COVID-19 pandemic in Brazil, along with the associated response measures, the COVID-19 Brazil/Ireland Observatory was established. This initiative is led by the Study Design and Scientific Writing Laboratory at the FMABC University Center. COVID-19 is identified as a metabolic disorder caused by the SARS-CoV-2 virus and is associated with severe acute respiratory syndrome (SARS). Predominant symptoms include fever ($\geq 37.8^{\circ}\text{C}$), cough, myalgia, fatigue, headache, dyspnea, upper respiratory, and gastrointestinal manifestations. The Ministry of Health designates flu syndrome as the most prevalent presentation, potentially progressing to pneumonia and SARS, characterized by respiratory distress and oxygen saturation levels falling below 95%. Elevated levels of angiotensin-converting enzyme 2 (ACE2), particularly in individuals with underlying health conditions, are correlated with respiratory symptoms⁸⁻¹⁰.

The SARS-CoV-2 virus was initially identified in the central region of China, specifically in the city of Wuhan, in December 2019. Demonstrating high transmissibility, it profoundly affected global health and the economy. Responding swiftly to the escalating situation, the World Health Organization (WHO) declared it a pandemic. In light of the increasing global cases, the WHO issued health recommendations, urging countries to adopt containment strategies and protective measures. These measures encompassed social distancing, quarantine protocols, the closure of educational institutions such as schools and universities, and the implementation of remote work policies¹¹⁻¹².

This virus is highly contagious, and one of the main transmission routes includes direct contact with airborne

droplets released during conversation, coughing, and sneezing from infected people. However, recent research suggests that the virus also can spread by air via aerosols¹³.

According to data from the World Health Organization (WHO) on Coronavirus - COVID-19, as of March 5, 2023, there have been 759,408,703 confirmed cases of COVID-19 globally, with 6,866,434 documented deaths attributed to the disease¹⁴. In February 2020, Brazil reported its initial confirmed case of COVID-19. Despite three years of sustained efforts to combat the pandemic, Brazil currently holds the unfortunate distinction of having the highest number of COVID-19 deaths globally, second only to the United States of America¹⁵. Given the elevated rate of spread, incidence, and mortality associated with COVID-19, managers of the Unified Health System (SUS) and their teams must formulate effective strategies for dealing with the situation. Developing comprehensive risk management plans at the national, state, municipal, and local levels is crucial. Understanding regional factors that influence the contagion and spread of the virus is essential in this endeavor. Additionally, employing time series studies is instrumental in analyzing the evolving patterns and behavior curves of the pandemic¹⁶. Hence, the objective of this study is to analyze the incidence, mortality, and lethality rates of COVID-19 in the States of Pará and Rio Grande do Sul and the trends of these key indicators over the period from 2020 to 2022.

METHODS

It is a Population-based ecological study with time series analysis. Time series are necessary to make valid inferences from the data, accounting for the correlation between repeated observations over time¹⁷.

The analysis of indicators for each State followed the protocol by Elmulsharaf and Siqueira (2021)¹⁸ with official secondary data from government public disclosure. The database was extracted from the electronic pages made

available by the Ministry of Health¹⁹ of the States of Pará and Rio Grande do Sul. All cases confirmed by laboratory, clinical, clinical-epidemiological, or/and clinical-imaging diagnosis of COVID-19 from February 2020 to December 2022 were included. The disease was classified according to the International Classification of Diseases, 10th edition (ICD-10), as “U07.1 COVID-19 – identified virus” or “U07.2 COVID-19, unidentified virus”²⁰. Cases without information on the date of notification or death were excluded.

Cases were classified based on the date of notification and fatal cases according to the date of death.

Characterization of the study site

Pará and Rio Grande do Sul, situated in distinct geographical regions, possess unique territorial attributes. Figure 1 depicts the map illustrating the geographic positioning of each state, and table 1 outlines the key sociodemographic features specific to each region.



Figure 1: Map of Brazil by regions

Source: Own authorship – IBGE²¹.

Table 1: Sociodemographic characteristics of Brazil and the States of Pará and Rio Grande do Sul according to the last Census carried out in Brazil in 2010

Sociodemographic characteristics	Description			
	BRASIL	PARÁ	RIO GRANDE DO SUL	
Region		North	South	
Number of municipalities	5.570	144	497	
capital	Brasília	Belém	Porto Alegre	
Territorial Extension (2021) - KM2	8.510.345,54	1.245.870,70	281.707,15	
Population (Last Census 2010) - People	190.755.799	7.581.051	10.693.929	
Estimated population (2021)	213.317.639	8.777.124	11.466.630	
Demographic Density (Last Census, 2010) - Inhabitants/km2	22,43	6,07	37,96	
Per capita home monthly income	R\$ 1.625,00	R\$ 1.061,00	R\$ 2.087,00	
Human Development Index (HDI) (Last Census, 2010)	0,699	0,646	0,746	
Basic Health Units of the Unique Health System - SUS (2009)*	63.184	2.300	3.868	
	Ambulatory SUS*	52.394	2.019	3.066
	SUS Dialysis*	923	16	81
establishments	SUS Emergency*	5.553	210	327
	SUS Internment*	5.415	218	324
	SUS ICU/CTI*	1.099	25	71
Number of beds for hospitalization in health facilities (2009)*	431.996	13.720	31.055	
	Public*	152.892	5.830	4440
beds	Private*	279.104	7.890	26615

Source: Brazilian Institute of Geography and Statistics (IBGE, 2021)²¹. Note 1: 2010 Census; SUS=Unified Health System.

Statistical analysis of data

The number of COVID-19 cases and deaths were described by absolute (n) and relative frequency (%).

The incidence rate (number of cases per 100.000 inhabitants), mortality (number of deaths per 100.000 inhabitants), and lethality (%) were calculated for each State as described in the formulas (1), (2), and (3):

$$\text{Incidence} = \frac{\text{number of cases}}{\text{number inhabitants}} \times 100.000 \quad (1) \quad \text{Mortality} = \frac{\text{number of deaths}}{\text{number inhabitants}} \times 100.000 \quad (2) \quad \text{Lethality} = \frac{\text{number of deaths}}{\text{number of cases}} \times 100 \quad (3)$$

Table 2: projection of the population of Brazil and Federation Units by sex and age for the period 2010-2060 (2018 edition)

Federation Region/Unit	2020	2021	2022
North Region	18.672.591	18.906.962	19.133.894
For	8.690.745	8.777.124	8.861.974
South Region	30.192.315	30.402.587	30.606.047
Rio Grande do Sul	11.422.973	11.466.630	11.507.906

Source: IBGE/Research Directorate. Population Coordination and Social Indicators. Management of Studies and Analysis of Demographic Dynamics (DATASUS, 2023)^{21,22}.

Prais-Winsten regression was applied to examine indicator trends, and the daily percentage change (DPC) was determined to classify trends as increasing, decreasing, or stationary. Stationary trends were considered when $p > 0.05$.

We followed the methodological guidelines proposed by Antunes and Cardoso (2015)²³ for the construction of time series, considering a significance level of 95%, according to the equations below (1), (2), and (3):

$$VPD = (10\beta - 1) \times 100\% \quad (1)$$

$$(IC95\%) = (10\beta_{\text{max}} - 1) \times 100\% \quad (2)$$

$$(IC95\%) = (10\beta_{\text{min}} - 1) \times 100\% \quad (3)$$

Where β is the linear regression slope, the indices ul mean the upper limit, and ll is the lower limit of the confidence level.

Statistical analyses were performed using STATA 14.0 software (College Station, TX, USA 2013).

Legal and ethical aspects

The data obtained from the information systems maintained by the State Health Department are official, enabling their use as a feasible tool for analyzing the epidemiological indicators of COVID-19. As this is public and widely accessible data without patient identification, the Scientific Research Ethics Committee does not need to assess this research, respecting the institutional precepts of resolution 466/12.

RESULTS

In the State of Pará, from January 2020 until December 2022, a total of 860,013 cases and 21,504 deaths were recorded through the Ministry of Health's Coronavirus Panel.

The first cases confirmed by COVID-19 in March 2020 correspond to <0.001% of the total cases throughout

The study considered the Population Projection of the Federation Units from 2000 to 2060 to determine the number of inhabitants. Specifically, population estimates for 2020, 2021, and 2022 were utilized. This approach ensures a comprehensive understanding of the impact of the pandemic on these regions relative to their demographic dynamics during the specified timeframe²².

the analyzed period. As for deaths, the first records appeared in April of the same year, corresponding to a relative frequency of 0.96% of deaths. In 2020, the state of Pará reported a total of 29,352.9 confirmed cases and 718.3 deaths due to COVID-19. Notably, the months with the highest confirmed cases were June (7.586%), July (5.985%), and August (5.217%). Regarding deaths, the standout months were May (12.625%), June (9.286%), and July (3.757%).

Moving to 2021, the number of cases and deaths in Pará amounted to 27,618.08 and 1,038, respectively. March, April, and May were significant months for both confirmed cases and deaths, representing 6.148%, 6.283%, and 5.238% of the total cases, and 20.414%, 11.881%, and 7.082% of the total deaths during the specified period.

In 2022, the number of COVID-19 cases in Pará was 19,588.92, with 155.41 deaths. January emerged as a notable month, contributing to 2.577% of the total cases, followed by February with 8.277% and July with 3.278%. Regarding deaths, the months of January, February, and March were significant, representing relative frequencies of deaths equivalent to 1.181%, 2.120%, and 1.362%, respectively.

Table 3 shows the monthly distribution of cases and deaths confirmed by COVID-19 in Pará and Rio Grande do Sul over time (2020 to 2022).

The first confirmed cases of COVID-19 in Rio Grande do Sul were registered in February 2020, corresponding to 0.001% of the total cases throughout the period analyzed, with the first death registered in March, representing 0.009 % of the total number of deaths about the period analyzed.

In 2020, the number of cases and deaths confirmed by COVID-19 was 42,547.33 and 770.25, respectively. The months with the highest number of cases were October (1,956%), November (4,163%) and December (4,202%). Regarding deaths, the months that stood out were July (3.344%), August (3.861%) and December (5.075%).

In 2021, the number of cases and deaths confirmed

by COVID-19 was 83,001.58 and 2,273.91, respectively. February, March and May stand out for cases, being 6.487%, 6.852%, and 4.657%, respectively, concerning

the total period. However, for deaths, the months with the highest number of records were March (20.303%), April (10.900%) and May (7.126%).

Table 3: Monthly distribution of cases and deaths confirmed by COVID-19 in the States of Pará and Rio Grande do Sul, Brazil, from January 2020 to December 2022

Year	Month	Confirmed Cases		Confirmed Deaths	
		absolut frequency (n)	relative frequency (%)	absolut frequency (n)	relative frequency (%)
PARÁ					
2020	January	0	0	0	0
	February	0	0	0	0
	March	21	0,002	0	0
	April	2.844	0,330	208	0,960
	May	35.085	4,079	2.715	12,625
	June	65.245	7,586	1.997	9,286
	July	51.479	5,985	808	3,757
	August	44.871	5,217	418	1,943
	September	30.893	3,592	427	1,985
	October	22.470	2,612	165	0,767
	November	17.629	2,049	172	0,799
	December	22.992	2,673	273	1,269
	Total 2020	293.529	34,125	7.183	33,391
2021	January	35.260	4,099	448	2,083
	February	35.337	4,108	955	4,441
	March	52.880	6,148	4.390	20,410
	April	54.036	6,283	2.555	11,880
	May	45.055	5,238	1.523	7,082
	June	36.323	4,223	965	4,487
	July	19.519	2,269	579	2,692
	August	11.341	1,318	405	1,883
	September	7.521	0,874	205	0,953
	October	7.097	0,825	87	0,404
	November	10.281	1,195	155	0,720
	December	16.767	1,949	189	0,878
	Total 2021	331.417	38,529	12.456	57,913
2022	January	22.165	2,577	254	1,181
	February	71.187	8,277	456	2,120
	March	34.651	4,029	293	1,362
	April	11.629	1,352	175	0,813
	May	9.113	1,059	106	0,492
	June	8.173	0,950	90	0,418
	July	28.194	3,278	80	0,372
	August	21.015	2,443	192	0,892
	September	7.986	0,928	117	0,544
	October	4.854	0,564	35	0,162
	November	7.046	0,819	35	0,162
	December	9.054	1,052	32	0,148
	Total 2022	235.067	27,328	1.865	8,666
Total triennium	860.013	100,00	21.504	100,00	

Continuation - Table 3: Monthly distribution of cases and deaths confirmed by COVID-19 in the States of Pará and Rio Grande do Sul, Brazil, from January 2020 to December 2022

Year	Month	Confirmed Cases		Confirmed Deaths	
		absolut frequency (n)	relative frequency (%)	absolut frequency (n)	relative frequency (%)
RIO GRANDE DO SUL					
2020	January	0	0	0	0
	February	33	0,001	0	0
	March	1.264	0,043	4	0,009
	April	3.607	0,123	60	0,144
	May	10.175	0,347	182	0,437
	June	25.581	0,873	440	1,057
	July	57.060	1,948	1.391	3,344
	August	62.303	2,127	1.606	3,861
	September	48.290	1,649	1.282	3,082
	October	57.298	1,956	1.000	2,404
	November	121.909	4,163	1.167	2,805
	December	123.048	4,202	2.111	5,075
	Total 2020	510.568	17,432	9.243	22,218
2021	January	93.303	3,186	1.776	4,269
	February	189.941	6,487	2.048	4,923
	March	200.621	6,852	8.445	20,303
	April	96.858	3,308	4.534	10,900
	May	136.372	4,657	2.964	7,126
	June	104.827	3,580	2.895	6,960
	July	46.802	1,598	1.697	4,079
	August	31.093	1,061	796	1,913
	September	26.665	0,910	616	1,480
	October	31.607	1,079	664	1,596
	November	18.519	0,632	595	1,430
	December	19.411	0,662	257	0,617
	Total 2021	996.019	34,012	27.287	65,593
2022	January	559.912	19,123	678	1,630
	February	237.036	8,095	1.431	3,440
	March	52.772	1,802	606	1,456
	April	36.897	1,260	196	0,471
	May	115.364	3,940	293	0,704
	June	94.756	3,236	482	1,158
	July	87.758	2,997	425	1,021
	August	47.428	1,619	356	0,855
	September	9.543	0,325	180	0,432
	October	3.776	0,128	59	0,141
	November	39.493	1,348	72	0,173
	December	136.587	4,665	286	0,687
	Total 2022	1.421.322	48,538	5.064	12,168
Total triennium	2.927.909	100,00	41.594	100,00	

In 2022, until July, the number of cases and deaths confirmed by COVID-19 was 118,443.5 and 422, respectively. January represents 19.123% of the total cases, followed by February, 8.095%, and December, 4.665%. Regarding the deaths, the months with the highest number were January, February, and March, with the relative frequencies equivalent to 1.630%, 3.440%, and 1.456, respectively.

For both States, table 4 shows the mortality, lethality, and incidence rates of COVID-19.

When comparing lethality between Para and Rio Grande do Sul, it was noted that during the period analyzed, the total rate remained higher in Pará, with April/2020 being highlighted (7.313% - 1.663 %), May/2020 (7.738% - 1.788%) and March/2021 (8.301% - 4.209%).

When comparing incidences, Rio Grande do Sul stands out compared to Pará, presenting the highest rates. In 2022, it was the highest incidence rate for COVID-19

in Rio Grande do Sul, with a total of 12,396.289/100,000 inhabitants, compared to a rate of 2,680.333/100,000 inhabitants in Pará. In 2020, the rate was higher by 1.31 times, and in 2021, the rate was 2.27 times higher.

Although lethality in Pará was higher throughout the period, mortality was higher in Pará than in Rio Grande do Sul only in 2020, reaching a rate of 83.301/100,000 inhabitants against 80.859/100,000 inhabitants. For 2021 and 2022, Rio Grande do Sul recorded a mortality rate of 2.08 and 2.09 times higher than Pará, respectively.

The trends in mortality, lethality, and incidence rates of COVID-19 in Pará and Rio Grande do Sul are shown in Table 5.

Mortality rates in 2020 showed an increasing trend in Rio Grande do Sul and remained stationary in Pará. In 2021 and 2022, the trends were decreasing for both states.

Lethality rates showed decreasing trends for

Table 4. Monthly distribution of mortality, lethality and incidence rates of COVID-19 in the States of Pará and Rio Grande do Sul, Brazil, from January 2020 to July 2022

Year	Month	PARÁ			RIO GRANDE DO SUL		
		Mortality	Incidence	Lethality	Mortality	Incidence	Lethality
2020	January	0	0	0	0	0	0
	February	0	0	0	0	0,289	0
	March	0	0,37	0	0,035	11,071	0,316
	April	2,410	32,959	7,313	0,525	31,593	1,663
	May	31,464	406,598	7,738	1,594	89,122	1,788
	June	23,143	756,121	3,06	3,853	224,062	1,72
	July	9,363	596,588	1,569	12,183	499,785	2,437
	August	4,844	520,008	0,931	14,066	545,708	2,577
	September	4,948	358,017	1,382	11,228	422,9696	2,654
	October	1,97	260,403	0,734	8,758	501,87	1,745
	November	1,993	204,301	0,975	10,221	1067,795	0,957
	December	3,163	266,453	1,187	18,49	1077,771	1,715
	Total 2020	83,301	3401,823	2,447	80,958	4472,039	1,81
2021	January	5,143	410,614	1,27	15,52	815,388	1,903
	February	11,56	414,506	2,702	17,897	1659,922	1,078
	March	21,066	607,092	8,301	73,802	1753,256	4,209
	April	29,332	620,364	4,728	39,623	846,456	4,681
	May	17,484	517,257	3,38	25,902	1191,775	2,173
	June	11,078	417,008	2,656	25,299	916,098	2,761
	July	6,647	224,089	2,966	14,83	409,009	3,625
	August	4,649	130,201	3,571	6,956	271,726	2,56
	September	2,353	86,345	2,725	5,383	233,029	2,31
	October	0,998	81,477	1,225	5,802	276,218	2,1
	November	1,779	118,031	1,507	5,199	161,84	3,212
	December	2,169	192,494	1,127	2,245	169,635	1,323
	Total 2021	114,266	3819,484	3,758	238,465	8704,355	2,739
2022	January	2,889	258	1,145	5,913	4883,363	0,121
	February	5,188	809,943	0,64	12,48	2067,348	0,603
	March	3,333	394,248	0,845	5,285	460,259	1,148
	April	1,991	132,311	1,504	1,709	321,803	0,531

Continuation - Table 4. Monthly distribution of mortality, lethality and incidence rates of COVID-19 in the States of Pará and Rio Grande do Sul, Brazil, from January 2020 to July 2022

Year	Month	PARÁ			RIO GRANDE DO SUL		
		Mortality	Incidence	Lethality	Mortality	Incidence	Lethality
	May	1,206	103,684	1,163	2,555	1006,165	0,253
	June	1,023	92,989	1,101	4,203	826,429	0,508
	July	0,91	320,782	0,283	3,706	765,39	0,484
	August	2,184	239,102	0,913	3,104	413,65	0,75
	September	1,331	90,862	1,465	1,569	83,23	1,886
	October	0,386	55,227	0,721	0,514	32,932	1,562
	November	0,398	80,167	0,496	0,627	344,444	0,182
	December	0,364	103,013	0,353	2,494	1191,265	0,209
	Total 2022	21,208	2680,333	0,793	44,166	12 396,289	0,356
	Total triennium	218,775	9901,641	2,5	363,59	25 572,683	1,42

Source: Information extracted from the Coronavirus Panel on January 12, 2023, available at: < https://covid.saude.gov.br>24.

Table 5: Estimates of Prais-Winsten regression and daily percentage variation (DPV) of mortality, lethality and incidence rates of COVID-19 in the States of Pará and Rio Grande do Sul, Brazil, from January 2020 to December 2022

Rate/year	Pará					Rio grande do sul				
	Linear regression					Linear regression				
	β	P	VPD	95%CI	Trend	β	P	VPD	95% CI	Trend
Mortality										
2020 to 2022	-0.0011841	<0.001	-0.30	-0.33: -0.21	Descending	0.0002123	0.630	0.05	-0.15: 0.25	Stationary
2020	-0.0013088	0.217	-0.30	-0.78: 0.18	Stationary	0.007	<0.001	1.16	1.31: 2.02	Growing
2021	-0.003438	<0.001	-0.80	-0.99: -0.59	Descending	-0.003	<0.001	-0.76	-1.02: -0.50	Descending
2022	-0.002467	<0.001	-0.60	-0.70: -0.43	Descending	-0.002	<0.001	-0.61	-0.82: -0.40	Descending
Lethality										
2020 to 2022	-0.000641	<0.001	-0.20	-0.19: -0.11	Descending	-0.0006	<0.001	-0.14	-0.20: -0.08	Descending
2020	-0.003552	<0.001	-0.80	-1.05: -0.58	Descending	-0.0002	0.305	-0.06	-0.16: 0.05	Stationary
2021	-0.000695	0.022	-0.20	-0.30: -0.02	Descending	-0.0002	0.473	-0.07	-0.24: 0.11	Stationary
2022	-0.000531	0.156	-0.10	-0.29: 0.05	Stationary	0.001	0.107	0.25	-0.05: 0.56	Stationary
Incidence										
2020 to 2022	-0.000203	0.200	-0.10	-0.12: 0.02	Stationary	0.0009	0.122	0.22	-0.06: 0.51	Stationary
2020	0.007291	<0.001	1.69	0.82: 2.58	Growing	0.007	<0.001	1.70	1.31: 2.09	Growing
2021	-0.002774	<0.001	-0.60	-0.64: -0.83	Descending	-0.002	<0.001	-0.64	-0.85: -0.43	Descending
2022	-0.002247	<0.001	-0.50	-0.52: -0.73	Descending	-0.002	0.295	-0.46	-1.32: 0.41	Stationary

2020 and 2021 and remained stationary in 2022 in Pará; however, in Rio Grande do Sul, they remained stationary throughout the analyzed period (2020 to 2022).

Incidence rates showed increasing trends during 2020, both in Pará with a DPC of 1.69% ($p < 0.05$) and 1.70% ($p < 0.05$) in Rio Grande do Sul. In 2021, the incidence decreased ($p < 0.05$) in both states, with a DPC of 0.60% in Pará and 0.64% in Rio Grande do Sul; and continued this trend in Pará in 2022 (DPC of -0.50% $p < 0.05$), remaining stationary in Rio Grande do Sul, with a non-significant p -value ($p > 0.05$).

DISCUSSION

The distinct socioeconomic vulnerabilities in the

North and South regions of Brazil underscore the need to identify factors influencing the evolution of COVID-19 epidemiological indicators. Understanding the unique pandemic situations in different states is crucial for devising effective disease control strategies. In this study, we delve into the analysis of COVID-19 incidence, mortality, and lethality in Pará and Rio Grande do Sul, examining trends from 2020 to 2022.

Throughout this period, both states confronted critical episodes. In Pará, a significant surge occurred between May and June 2020, marked by 5,520 deaths and 161,595 new cases of COVID-19. Meanwhile, in Rio Grande do Sul, another notable period unfolded between November and December, witnessing 3,278 deaths and

244,947 new cases. These episodes serve as pivotal points for understanding the dynamics and challenges faced by each state in managing the impact of the pandemic. The second critical period unfolded between March and May 2021 in Pará, witnessing a nearly doubling of both deaths and COVID-19 cases compared to the most critical period of the previous year. This significant surge played a decisive role in overwhelming the health system²⁵, as previously analyzed concerning the capacity of hospital infrastructure to cope with the pandemic and the effectiveness of government actions in combating the pandemic²⁶.

While scrutinizing the evolution of COVID-19 epidemiological indicators throughout 2020, 2021, and 2022 in Pará and Rio Grande do Sul, notable differences and distinctive aspects emerge. Each year unfolds a unique scenario, emphasizing the dynamic and evolving nature of the pandemic in these regions. In 2020, the peak number of COVID-19 cases in Pará was recorded in June (65,245), while in Rio Grande do Sul, it occurred in December (123,048). Despite the higher absolute numbers in Rio Grande do Sul, the incidence rate in Pará for the same period was 3,401.82 per 100,000 population, which was lower than that in Rio Grande do Sul, which reached 4,472.03 per 100,000. It's noteworthy that both states reported incidence rates higher than the national average for this period, which stood at 3,129 per 100,000 population. This information underscores the variations in the spread of COVID-19 between these states during 2020.

In 2020, the incidence in Pará was still lower than the North region's average (4,262.4/100,000 inhabitants). Notably, Roraima in the North region reported the highest incidence in the country, reaching 10,678 cases per 100,000 inhabitants. The seven states in the North region collectively accounted for 11.9% of the country's total COVID-19 cases. Among these, the municipalities with the highest number of new cases were Manaus/AM (2,026), Belém/PA (1,686), and Boa Vista/RR (1,328). In July 2020, Pará held the fourth position with one of the highest COVID-19 case counts nationally. The findings from Lélis da Silva F. *et al.*, (2021)²⁷ highlight that the most significantly affected states in the North were Pará and Amazonas. According to the study, one week after the notification of the first case of COVID-19 in Pará, 0.82% of municipalities reported cases. This figure increased to 5.56% in the second week and substantially rose to 15.3% in the third week. Seven weeks after the initial case, 81.8% of municipalities had reported cases of COVID-19. The highest case numbers were concentrated in the capital's metropolitan region, specifically in and around Belém.

Contrastingly, the incidence of COVID-19 in Rio Grande do Sul exceeded that of the South region (3,471.7/100,000), with Santa Catarina registering the highest incidence rate at 5,493.6 cases per 100,000 inhabitants. According to the Ministry of Health's epidemiological bulletin (2020), by the end of the year, Rio Grande do Sul ranked as the third federative unit with the highest number of COVID-19 cases after São Paulo and Santa Catarina. Notably, there was an increase in the number of cases in Rio Grande do Sul (+26%), Santa Catarina (+16%), and Paraná (+11%), collectively representing 15.8% of total COVID-19 cases in Brazil.

The municipalities with the highest frequency of new cases were Porto Alegre/Rio Grande do Sul (4,179), Joinville/SC (3,540), and Florianópolis/SC (2,627).

In terms of deaths, in 2020, Pará reported its highest number in May (2,715), while Rio Grande do Sul peaked in December (2,111). The mortality rate in Pará was 83.30 deaths per 100,000 inhabitants, and in Rio Grande do Sul, it was 80.95 deaths per 100,000 inhabitants. Notably, both states had lower mortality rates than the national average of 84 deaths per 100,000 inhabitants. Furthermore, Pará exhibited a lower mortality rate than the North region, with 92 deaths per 100,000 inhabitants. On May 6, the government of Pará declared a lockdown in the capital and in municipalities close to the metropolitan region to reduce human trafficking and try to control the spread of the pandemic²⁷.

In contrast, Rio Grande do Sul had the highest mortality rate in the Brazilian South region. The municipalities with the highest number of deaths from COVID-19 were Porto Alegre, Curitiba, and Blumenau²⁸.

The values of the number of cases and deaths impacted the trend behavior of the analyzed indicators; thus, it is observed that at the end of 2020, the incidence trend was increasing in both Pará and Rio Grande do Sul. Mortality was stationary in Pará and increasing in Rio Grande do Sul, with decreasing lethality in Pará and stationary in Rio Grande do Sul.

The evolution of epidemiological indicators in 2021 in Rio Grande do Sul was marked by an aggressive second wave of the pandemic, the implementation and progress of the vaccination program against COVID-19 conducted by the Unified Health System (Sistema Único de Saúde - SUS), and at the end of December the arrival of the Omicron variant.

The quarter formed by March, April, and May 2021 recorded the highest volume of cases and deaths in Pará and Rio Grande do Sul of the entire period analyzed (table 2). These numbers coincide with national data; in fact, on March 23, 3,251 deaths were recorded in one day in Rio Grande do Sul. One month later, on April 8, Brazil sadly registered a new record in the number of fatalities, recording 4,249 deaths from COVID-19 in 24 hours in Rio Grande do Sul, according to data from CONASS (2021)²⁹.

In the subsequent months, from June to November 2021, both Pará and Rio Grande do Sul experienced a decline in cases and deaths from COVID-19. This reduction can be attributed to the consistent implementation of non-pharmacological measures and the successful coverage of the vaccination program in these states. The combination of ongoing public health measures and widespread vaccination played a crucial role in mitigating the impact of the virus during this period.

However, mortality and incidence in 2021 were higher in Rio Grande do Sul than in Pará. The higher incidence rates of COVID-19 in Rio Grande do Sul compared to Pará in 2021 and 2022 were divergent from other studies. The highest incidence rates of COVID-19 occurred in Brazil's North and Northeast regions, where areas with lower human development converge⁷.

Pará initiated its vaccination program on January 19, 2021. By September 24 of the same year, it had achieved

a vaccination rate of 46.04% for the first dose and 29% for the second or single dose. In contrast, by December 2021, Rio Grande do Sul had a higher vaccination coverage, with 70.3% of the population receiving two doses and 80.9% receiving at least the first vaccine against COVID-19²⁸. These vaccination figures underscore the progress made in immunization efforts in both states, contributing to the observed decline in COVID-19 cases and deaths during the mentioned period. At the national level, by December 2021, Brazil had reached 80% of its target population fully vaccinated³⁰.

The national immunization strategy against COVID-19 was implemented in stages, following the prioritized order of groups defined by the PNI (National Immunization Program)³¹. The strategy aimed to prioritize individuals at the highest risk of developing severe forms of the disease and facing an increased risk of death. This included specific groups such as health professionals, older adults, institutionalized older people, individuals with comorbidities like hypertension and diabetes mellitus, and those with a high degree of social and economic vulnerability, such as indigenous people, quilombolas, riverside communities, and the population deprived of liberty³². This phased and targeted approach aimed to efficiently and equitably distribute the available vaccines, considering the varying degrees of vulnerability and risk across different population segments.

Mass vaccination against COVID-19 has proven to be an effective weapon in combating the pandemic. The WHO supported more countries to have access to vaccines to prevent people from becoming more seriously ill and, therefore, save more lives.

The increase in COVID-19 cases and deaths observed in both Pará and Rio Grande do Sul in December 2021, continuing into January and February 2022, aligns with the emergence of the Omicron variant. This variant, first identified in South Africa and Botswana in November, was classified as a variant of concern by the World Health Organization³³. The designation was due to its numerous mutations³⁴, making it more transmissible than the original strain of the virus. The rise in cases and deaths during this period underscores the challenges posed by the Omicron variant and its potential impact on the trajectory of the COVID-19 pandemic.

Furthermore, at the end of 2021, coinciding with the year-end holiday period, the population felt more confident due to the protection of vaccines, and there was a relaxation in the maintenance of non-pharmacological measures against COVID-19, which favored the spread of the virus in all regions of the country³⁵. The results of this study reflect the reality of other regions of Brazil during January and February 2022. Pará totaled 93,352 cases of COVID-19, and Rio Grande do Sul registered 796,948, the highest values of the entire period analyzed. This situation impacted the incidence rates, which were also the highest in the three years analyzed.

The influence of the extensive vaccination program is evident in the December 2022 trends, where mortality decreased in both Pará and Rio Grande do Sul. Despite the significant increase in cases attributed to the Omicron variant, the lethality trend remained stable in both states.

The incidence decreased in Pará and remained steady in Rio Grande do Sul for 2022. However, considering the entire period, the incidence shows a consistent trend in both states, indicating the importance of ongoing monitoring of cases and morbidity across various age groups.

In both states, the spread of the virus and the high number of cases and deaths throughout the analyzed period compromised the structure of the public and private health systems due to the exponential increase in primary health services and the need for more complex services that require hospitalization and invasive mechanical ventilation²⁷.

Despite the relevance of these epidemiological data for understanding the evolution of the disease for possible planning following statistics, some factors such as the rapid spread of the virus, the reduced number of tests carried out, especially at the beginning of the pandemic, the asymptomatic cases that often, go unnoticed by the health system, among other conditions, making it difficult to estimate the actual number of cases, generating considerable underreporting throughout the country³⁶.

The evolution of the pandemic is influenced by several factors, where the context of vulnerability is considered a determining factor in the incidence and mortality of COVID-19. In this scenario, it is essential to mention the presence of indigenous groups in each region. According to the last Census carried out by IBGE²¹, Rio Grande do Sul had a population of approximately 32,989 indigenous people, and Pará had approximately 60,000 people of indigenous origin. These communities are significantly more vulnerable to epidemics because they live in remote locations, with precarious socioeconomic and health conditions, they live in remote places, with a lack of human resources in the health area, and communication limitations due to the native language. Living in collective houses and sharing utensils favors the spread of the virus. It is stated that the indigenous population affected by COVID-19 is underreported³⁷.

The total number of cases and victims and the corresponding incidence, mortality, and lethality caused by the coronavirus during 2020, 2021, and 2022 in Pará and Rio Grande do Sul show three possible pandemic waves. The first occurred between March and November 2020, marked by high circulation of the virus³⁸. The second, from February to July 2021, marked the emergence of several variants, and the third, from December 2021 to December 2022, was characterized by the presence of the Omicron variant. From January 2020 to May 2021, changes in the frequency of dominant lineages were recorded in Brazil, according to data from the Fiocruz Genomic Network. At the beginning of the epidemic, it was mainly driven by the B.1.1.28 and B.1.1.33 lineages, which were the most prevalent until October 2020³⁹. After this period, there was an increase in the circulation of two variants of national origin, P.1 and P.2, originating from the B.1.1.28 lineage. Regarding the notification of variants of concern and interest in public health, four variants classified as VOC and two (Zeta and Lambda) of the seven variants classified as VOI by the WHO were registered in Brazil⁴⁰.

Since the beginning of the pandemic, replacements of variants have been observed, which remained throughout

the period analyzed^{37,41}.

Therefore, it is a priority to monitor the behavior of different variants to adjust control measures. According to the Pan American Health Organization⁴⁰, the best way to contain the spread of the virus, regardless of the variant, is to maintain infection quarantine, patient isolation, physical distancing, use of masks, and vaccination.

This study presents some limitations in the spatial analysis arising from the methodology of ecological studies and secondary database analysis, such as delays in notifications, changes in the household that can cause distortions in the number of cases and deaths per city or municipality, and underreporting cases of the disease.

Furthermore, the results presented are partial data as the pandemic continues to be studied. The number of

cases found may be higher, considering the limitations of mass testing for detecting COVID-19.

CONCLUSION

The spread of the virus and the high number of cases and deaths throughout the analyzed period compromised the structure of the health system due to the exponential increase in primary health services.

The positive impact of the vaccination program is reflected in the evolution of the pandemic and the stationary trend in incidence for both States.

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Resumo

Introdução: panorama da progressão da pandemia de COVID-19 nos Estados do Pará e Rio Grande do Sul, Brasil e as ações de combate ao vírus SARS-CoV-2 as variantes e vacinação, no período de 2020 a 2022. O contexto de vulnerabilidade socioeconômica da região Norte é diferente da região Sul. É fundamental identificar os elementos que impactam a evolução dos indicadores epidemiológicos da COVID-19 e entender a situação da pandemia nos diferentes Estados do país, para facilitar a busca de estratégias de controle da doença.

Objetivo: analisar a incidência, mortalidade e letalidade nos estados do Pará e Rio Grande do Sul e as tendências destes indicadores no período de 2020 a 2022.

Método: estudo ecológico com série temporal, a partir de dados públicos e oficiais disponíveis na Secretaria de Saúde dos Estados do Pará e do Rio Grande do Sul, incluindo todos os casos e óbitos por COVID-19 que ocorreram durante fevereiro de 2020 a dezembro de 2022. As taxas de letalidade, mortalidade e incidência foram calculadas. Utilizou-se a análise de regressão do Prais-Winsten, as tendências foram classificadas como estacionárias, crescentes ou decrescentes. Diferenças significativas foram consideradas quando $p < 0,05$.

Resultados: ao comparar a letalidade entre os Estados do Para e o Rio Grande do Sul, notou-se que durante o período analisado, a taxa total manteve-se maior no estado do Pará, sendo destacado os meses de abril/2020, maio/2020 e março/2021. As taxas de incidência apresentaram tendências crescentes durante o ano de 2020, tanto no Pará com VPD de 1,69% ($p < 0,05$) quanto no RS com VPD de 1,70% ($p < 0,05$). Em 2021 a incidência foi decrescente ($p < 0,05$) nos dois estados, com uma taxa de redução diária de 0,60% no Pará e 0,64% no RS; e continuou nesta tendência no Pará em 2022 (VPD de -0,50% $p < 0,05$), ficando estacionária no RS, com valor de p não significativo ($p > 0,05$).

Conclusão: o impacto positivo do programa de vacinação reflete-se na evolução da pandemia. Para todo o período analisado a incidência apresenta tendência estacionária para ambos Estados, indicando que o número de casos e a morbidade entre as diferentes faixas etárias e grupos devem continuar sendo monitorado.

Palavras-chave: COVID-19, SARs-CoV-2, incidência, mortalidade, letalidade, tendência.

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