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ORIGINAL ARTICLE

Epidemiological evolution of COVID-19: a three-year perspective on coping with the Pandemic in the States of Rio Grande do Sul and Paraná, Southern region of Brazil

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Abstract

Introduction: The novel Coronavirus disease (COVID-19) is caused by SARS-CoV-2 and represents the agent responsible for a respiratory and metabolic disease with a high fatality rate, remaining a public health problem to this day. There has been an exacerbation of social inequalities experienced in Brazil and worldwide. Notably, the absence of a consolidated and universal healthcare system has contributed to the increased inequalities and survival opportunities for those affected by SARS-CoV-2 infection and manifestation of COVID-19. The southern region has become the second region with the highest number of cases in Brazil.

Objective: To avaluate the epidemiological outcomes of incidence, lethality, and mortality among the states of Rio Grande do Sul and Paraná in the southern region of Brazil.

Methods: An ecological time-series study was conducted using official secondary data on COVID-19 cases and deaths publicly disclosed by the health departments of the states of Rio Grande do Sul and Paraná. Time series were constructed applying the Prais-Winsten regression model. Statistical analyses were performed using STATA 14.0 software.

Results: It was observed that for the state of Rio Grande do Sul, the trends regarding incidence were increasing in 2020 and decreasing in 2021 ($p<0.05$). Regarding mortality, it increased in 2020 and decreased in 2021 and 2022 ($p<0.05$). When assessing lethality, a decreasing trend was observed for the entire period ($p<0.05$). In relation to Paraná, incidence increased in 2020 and over the entire period, while it decreased in 2021 and 2022 ($p<0.05$). Mortality was stationary in 2020 and decreased in 2021 and 2022 ($p<0.05$).

Conclusion: The COVID-19 pandemic is a serious public health problem in the states of Paraná and Rio Grande do Sul. Paraná presented a more severe epidemiological outcome compared to Rio Grande do Sul.

Keywords: COVID-19, incidence, case fatality, mortality, trend.

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Authors summary

Why was this study done?
This study was undertaken to analyze the panorama of the COVID-19 pandemic in the states of Paraná and Rio Grande do Sul, focusing on a detailed understanding of epidemiological indicators such as mortality, fatality rate, and incidence. Throughout the investigation, researchers highlighted significant differences between these two states, consistently emphasizing that Paraná consistently showed higher values in incidence, mortality, and fatality rate compared to Rio Grande do Sul.

What did the researchers do and find?
The researchers explored the impact of public management and preventive measures on the evolution of the pandemic. A relevant finding was the initially high fatality rate in Paraná, possibly associated with delays in implementing preventive protocols and a lack of population adherence to non-pharmacological methods for preventing COVID-19. These conclusions emphasize the importance of effective pandemic management, early implementation of preventive measures, and population engagement as critical factors that influenced the epidemiological outcomes in the analyzed states.

What do these findings mean?
The discoveries from this study hold significant implications, emphasizing the need to consider socioeconomic factors, social inequalities, and characteristics of urban infrastructure in disease spread. Additionally, they underscore the importance of evidence-based prevention and control policies, continuous monitoring, and the implementation of intervention strategies to mitigate the impacts of COVID-19. This is a call to maintain attention on the continuity of preventive measures, even in the face of vaccination progress, aiming to ensure a comprehensive approach to public health protection.

Highlights
This study was based on a comprehensive and comparative approach to the evolution of the COVID-19 pandemic in the states of Paraná and Rio Grande do Sul. Researchers emphasize the influence of factors such as public management, preventive measures, and socioeconomic characteristics on the disease's dynamics. Furthermore, the detailed temporal analysis, considering specific indicators such as lethality and incidence, provides valuable insights. The inclusion of elements like social inequalities and urban infrastructure reinforces the multifaceted understanding of virus spread. This integrated approach contributes to adapting regional public policies, highlighting the ongoing need for personalized strategies and vigilant monitoring amid the challenges of the pandemic.

INTRODUCTION

The COVID-19 pandemic is far from over. The SARS-CoV-2 virus and its variants continue to circulate. Three years into the global experience of the COVID-19 pandemic, its effects persist on global public health, the economy, and international relations among people and countries. A new work and commercial relationship is being experienced. There's clear scientific advancement, particularly in the field of drug development, with COVID-19 vaccines being tested in large, randomized controlled trials involving individuals across a wide age range, both sexes, different ethnicities, and those with known medical conditions. The world has changed!

The World Health Organization (WHO) was alerted in mid-December 2019 about several cases of pneumonia concentrated in the city of Wuhan, Hubei province, People's Republic of China. It was a new type of coronavirus not yet identified in humans. On January 7, 2020, Chinese authorities confirmed a new type of coronavirus, named SARS-CoV-2, responsible for causing the disease COVID-19[1,2].

Coronaviruses (CoV) are a broad family of viruses that can cause a variety of conditions, from the common cold to more severe illnesses such as Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS-CoV)[2].

The novel coronavirus (nCoV) is a new strain of coronavirus that had not previously been identified in humans. Known as 2019-nCoV or COVID-19, it was only detected after reports of an outbreak in Wuhan, China, in December 2019[2].

The pathogen causing this outbreak was identified as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). As COVID-19 cases rapidly spread worldwide, the World Health Organization (WHO) declared it a pandemic on March 11, 2020[3].

The disease caused by the novel Coronavirus (COVID-19) is brought about by SARS-CoV-2 and is characterized as a respiratory and metabolic illness with a high fatality rate, continuing to pose a public health problem today[1,4]. Since its emergence in late 2019, the initial waves of the COVID-19 pandemic challenged the classical model of tackling communicable diseases due to the absence of strictly pharmacological actions in the public health portfolio.

Due to its high potential for transmission and global distribution, on January 30, 2020, the WHO declared the 'Novel Coronavirus' as a Public Health Emergency of International Concern (PHEIC). In Brazil, the epidemic was declared a Public Health Emergency of National Importance (PHENI) on February 3, 2020[5].

The first case of COVID-19 in Brazil was recorded on February 26, 2020, in the city of São Paulo. Subsequently, the disease spread rapidly, affecting all regions of Brazil regardless of their political, socioeconomic, and healthcare conditions[6].

In early 2020, only non-pharmacological measures such as social distancing, the use of face masks, and hand hygiene were reported. This was because Epidemiology presented solid evidence that social isolation would be the best strategy, allowing people to become infected at a slower pace, enabling the healthcare system to handle the full extent of severe cases of COVID-19 development[7].

These measures resulted in some societal damage, especially affecting vulnerable populations: the poor, women, and workers. Consequently, there was an exacerbation of social inequalities experienced in Brazil and worldwide. Notably, the absence of a consolidated and universal healthcare system contributed to increased

inequalities and survival opportunities for those affected by SARS-CoV-2 infection and manifestation of COVID-19[8]. Globally, as of April 12, 2023, there have been 762,791,152 confirmed cases of COVID-19, including 6,897,025 deaths reported by the WHO. The highest number of confirmed cases was concentrated in the European Continent with 275,110,560 confirmed cases, followed by the Western Pacific with 202,153,158 and the Americas with 191,814,9664.

According to the World Health Organization (WHO), as of July 9, 2023, there have been 768,237,788 confirmed cases of COVID-19, including 6,951,677 deaths reported to the WHO, with Brazil ranking sixth in the world in terms of COVID-19 cases, with 37,693,506 confirmed cases and 704,320 deaths[4,5].

It is known that Brazil has significant social inequalities that can influence the spread of COVID-19. There's a higher risk of illness in areas with high incidence rates and inequalities in income and wealth, as well as greater social vulnerability, poverty, and social inequalities in health9. Social inequality and poor housing conditions in Brazil contribute to the spread of COVID-19. Precarious housing made it difficult for individuals and families to practice social distancing, limited access to basic hygiene and personal protective products, and created barriers to accessing healthcare services for vulnerable populations[10].

The Southeast was the region with the highest number of cases, totaling 14,855,889, followed by the South region with 7,928,381, the Northeast with 7,736,349, the Midwest with 4,305,185, and finally, the North region with 2,863,450. The highest number of deaths occurred in the Southeast region[11].

The southern region of Brazil became the second region with the highest number of cases in the country. Rio Grande do Sul totaled 3,016,376 cases and 42,065 deaths as of April 19, 2023. The highest number of deaths was concentrated in the 70 to 79-year-old male group, of which 2,961,962 patients (98%) recovered[12].

The state of Paraná has a population of 11,443,208 people, with a population density of 57.42 inhabitants per square kilometer. Until April 17, 2023, in Paraná, 2,919,573 cases and 45,951 deaths due to COVID-19 were confirmed, totaling 2,235 cases and 68 deaths in the last 7 days, and 2,863,447 (98.08%) of patients have recovered. The average age of deaths was 65 years, more prevalent in females (57%), while the average age of cases was 39 years, more prevalent in males[13].

Paraná is one of Brazil's most developed states, ranking 7th in the Human Development Index (0.749), the highest in the country[14]. Its culture has been influenced by migration processes of both Brazilians and foreigners with strong European origins. The state's economy relies on agricultural and industrial activities, along with a robust tourism sector[14].

In comparison, Rio Grande do Sul represents approximately 5.4% of Brazil's population and has become the 6th most populous state in Brazil. It boasts the fourth-largest GDP and the sixth-highest HDI (0.780) in the country. It is a state with a higher number of elderly individuals and the second-highest life expectancy. Its population density is 38.62 inhabitants per square kilometer, with a population of 10,880,506 people[14].

Regarding the economy, Rio Grande do Sul holds a strong agricultural influence, producing around 90% of grapes and wines and 70% of rice. Additionally, it's the third-largest producer of soybeans and corn in the country and ranks third in pork production. Another economic sphere is its high degree of industrialization, with a focus on petrochemical, tobacco, footwear, construction, food, automotive, and naval industries within its industrial park[14].

As such, due to its vast continental size, Brazil presents a complex epidemiological scenario with climatic, vegetative, cultural, and socioeconomic divergences8. Notably, the spread of COVID-19 has shown heterogeneous dynamics influenced by socioeconomic determinants and variations in available healthcare services[3].

The fundamentals of syndemic theory are real and allow us to understand disease distribution, given that political-economic factors experienced over generations have resulted in social, cultural, and power inequalities. Consequently, these inequalities alter the distribution of health risks and resources, resulting in social and spatial clustering of epidemic diseases[15].

Thus, considering the impact of the COVID-19 pandemic on the socioeconomic sphere and the Brazilian healthcare system, given the regional heterogeneity and high number of cases and deaths in the states of Rio Grande do Sul and Paraná, this study aims to evaluate the epidemiological outcomes of incidence, fatality, and mortality between the states of Rio Grande do Sul and Paraná in the southern region of Brazil.

METHODS

Study design and location

An ecological time-series study was conducted16. Time-series analyses are necessary for making valid inferences from data, accounting for correlations among repeated observations over time[17].

Official secondary data on COVID-19 cases and deaths from the panels of the State Health Secretariat of Rio Grande do Sul (https://ti.saude.rs.gov.br/covid19/) and Paraná (https://www.saude.pr.gov.br/Pagina/Coronavirus-COVID-19) were used for analysis. The sociodemographic characteristics of Rio Grande do Sul and Paraná are presented in table 1.

Table 1: Sociodemographic Characteristics of Rio Grande do Sul and Paraná, Southern Region of Brazil

Sociodemographic characteristic	Rio Grande do Sul	Paraná
Region*	South	South
Number of municipalities*	497	284
State Capital*	Porto Alegre	Curitiba
Territorial extension* (2022)	281748 km²	199298981 km²
Estimated population (2021)	11466630 people	11597484 people
Population density* (last census, 2010)	39.79 hab/km²	40 hab/km²
Urban household situation (2010)*	9100291 people	8912692 people
Rural household situation (2010)*	1593638 people	1531834 people
Monthly household per capita income*	R$ 2087	R$ 1846
Human Development Index (HDI) (last census, 2010)*	0.746	0.749
Number of Basic Health Units of the Unified Health System (SUS) (2009)*	3868 establishments	4091 establishments
SUS outpatient*	3006 establishments	3307 establishments
SUS dialysis*	81 establishments	69 establishments
SUS emergency*	327 establishments	446 establishments
SUS hospitalization*	324 establishments	411 establishments
SUS ICU*	71 establishments	76 establishments
Number of beds for hospitalization in healthcare facilities (2009)*	31055 beds	26793 beds
Public*	4400 beds	6512 beds
Private*	26615 beds	20281 beds

Source: IBGE.

Sampling and Eligibility Criteria

All COVID-19 cases and deaths reported from March 2020 to December 2022 in the states of Rio Grande do Sul and Paraná were included. Occurrences were confirmed through laboratory, clinical, and clinical-epidemiological diagnoses. COVID-19 was categorized according to the International Classification of Diseases, 10th edition (ICD-10) as "U07.1 COVID-19, virus identified" or "U07.2 COVID-19, virus unidentified".

Deaths and cases were classified by the date of symptom onset; additionally, cases without information on notification or death date were excluded from the study. A second author verified the extracted data, and a third investigator conducted a final check in case of discrepancies. Finally, the information was recorded in an Excel spreadsheet (Microsoft Corporation, Redmond, WA, USA).

Statistical analysis

The number of COVID-19 cases and deaths were described by absolute frequency (n) and relative frequency (%). For each state, the incidence rate (number of cases per 100,000 inhabitants), mortality rate (number of deaths per 100,000 inhabitants), and fatality rate (%) were calculated as described below:

$$\text{incidence} = \frac{\text{number of cases}}{\text{number of inhabtants}} \times 100.000$$

$$\text{mortality} = \frac{\text{number of deaths}}{\text{number of inhabtants}} \times 100.000$$

$$\text{letality} = \frac{\text{number of deaths}}{\text{number of cases}} \times 100$$

For the population count, the Population Projection of each federative unit was considered. For the state of Rio Grande do Sul, the estimated population for the year 2020 (8,628,901 inhabitants), 2021 (8,710,364 inhabitants), and 2022 (8,789,130 inhabitants) was used. Meanwhile, for the state of Paraná, the estimated population was (11,516,840 inhabitants) for the year 2020, (11,597,484 inhabitants) for 2021, and (11,675,661 inhabitants) for 2022[14].

To analyze the trend, the Antunes and Cardoso protocol (2015)18 was used. Time series were constructed applying the Prais-Winsten regression model. It allowed for first-order autocorrelation to analyze the values of the time series and facilitate the assessment and classification of the incidence, mortality, and fatality into increasing, decreasing, or stable trends. Trends were classified as stable when the p-value was not significant ($p > 0.05$).

The probability (p) values and daily percent change (DPC), considering a significance level of 95%, were calculated using the equations below (1-2-3), where β represents the angular coefficient of the linear regression, the indices ul denote the upper limit, and ll is the lower limit of the confidence level.

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

$$(IC95\%)_{ul} = (10^{\beta\_max-1}) \times 100\% \quad (2)$$

$$(IC95\%)_{ll} = (10^{\beta\_min-1}) \times 100\% \quad (3)$$

To compare proportions, the two-tailed z-test was

used, considering differences significant when the p-value was < 0.05.

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

Ethical aspects

The data obtained from information systems maintained by the Ministry of Health are reliable, allowing their use as a feasible tool for analyzing COVID-19 epidemiological indicators. Since these are public data widely accessible, there is no need to seek approval from the Research Ethics Committee (CEP) for conducting this study.

RESULTS

Data extracted from the Coronavirus Panel database, spanning from 2020 to 2022, indicate that in the state of Rio Grande do Sul, 2,927,909 cases and 41,594 confirmed deaths (table 2) due to COVID-19 were reported, whereas in the state of Paraná, there were 2,888,258 cases and 45,815 deaths recorded (table 3).

Tables 2 and 3 display the absolute and relative frequencies per month of cases and deaths during the studied period for the analyzed states.

Table 2: Monthly distribution of confirmed COVID-19 cases and deaths in the state of Rio Grande do Sul, Brazil, from January 2020 to December 2022

Year	Month	Confirmed cases		Confirmed deaths	
		AF (n)	RF (%)	AF (n)	RF (%)
2020	January	0	0	0	0
	February	33	<0.01	0	0
	March	1264	<0,01	4	<0.01
	April	3607	0.12	60	0.14
	May	10 175	0.34	182	0.43
	June	25 581	0.87	440	1.05
	July	57 060	1.94	1391	3.34
	August	62 303	2.12	1606	3.86
	September	48 290	1.64	1282	3.08
	October	57 298	1.95	1000	2.40
	November	121 909	4.16	1167	2.80
	December	123 048	4.20	2111	5.07
2021	January	93 303	3.18	1776	4.26
	February	189 941	6.48	2048	4.92
	March	200 621	6.85	8445	20.30
	April	96 858	3.30	4534	10.90
	May	136 372	4.65	2964	7.12
	June	104 827	3.58	2895	6.96
	July	46 802	1.59	1697	4.07
	August	31 093	1.06	796	1.91
	September	26 665	0.91	616	1.48
	October	31 607	1.07	664	1.59
	November	18 519	0.63	595	1.43
	December	19 411	0.66	257	0.61
2022	January	559 912	19.12	678	1.63
	February	237 036	8.09	1431	3.44
	March	52 772	1.80	606	1.45
	April	36 897	1.26	196	0.47
	May	115 364	3.94	293	0.70
	June	94 756	3.23	482	1.15
	July	87 758	2.99	425	1.02
	August	47 428	1.61	356	0.85
	September	9543	0.32	180	0.43
	October	3776	0.12	59	0.14
	November	39 493	1.34	72	0.17
	December	136 587	4.66	286	0.68
Total	2 927 909	100.00	41 594	100.00	

Source: Information extracted from the Coronavirus Panel on January 12, 2023, available at: < https://covid.saude.gov.br/>. AF: Absolute Frequency (n); RF: Relative Frequency (%)

In Rio Grande do Sul, the first confirmed case of COVID-19 was registered in February 2020. In that month, the cases accounted for 0.001% of the total cases over the three years of analysis. Regarding deaths, the first record occurred in the month following the onset of the first case, equivalent to 0.009% of the total deaths in the period analyzed.

In the initial year, the total confirmed cases and deaths due to COVID-19 were 510,568 and 9,243, respectively. During this year, the months with the highest cumulative number of confirmed cases were August (2.12%), November (4.16%), and December (4.20%). Concerning deaths, they were July (3.33%), August (3.86%), and December (5.07%) in the year 2020.

In 2021, the total number of cases was 996,019, while the number of deaths was 27,287. There was a notable increase in cases during the months of February (6.48%), March (6.85%), and May (4.65%), and for deaths during March (20.30%), April (10.90%), and May (7.12%) in the same period.

In the final year of analysis, in 2022, the total number of confirmed cases and deaths due to COVID-19 was 1,421,322 and 5,064, respectively. The months of January (19.12%), February (8.09%), and December (4.66%) stood out for cases, while January (1.63%), February (3.44%), and March (1.45%) were notable for deaths.

Table 3: Monthly distribution of confirmed COVID-19 cases and deaths in the state of Paraná, Brazil, from January 2020 to December 2022

Year	Month	Confirmed cases		Confirmed deaths	
		AF (n)	RF (%)	AF (n)	RF (%)
2020	January	0	0	0	0
	February	0	0	0	0
	March	285	<0.01	6	0.01
	April	1747	0.06	110	0.24
	May	4647	0.16	125	0.27
	June	24 357	0.84	625	1.36
	July	57 817	2.00	1434	3.12
	August	58 679	2.03	1570	3.42
	September	49 528	1.71	1243	2.71
	October	35 626	1.23	826	1.80
	November	85 980	2.97	1048	2.28
	December	125 809	4.35	2325	5.07
2021	January	119 206	4.12	1990	4.34
	February	107 867	3.73	2044	4.46
	March	173 553	6.00	6517	14.22
	April	103 382	3.57	4516	9.85
	May	196 949	6.81	4928	10.75
	June	166 103	5.75	5443	11.88
	July	72 616	2.51	2625	5.72
	August	70 515	2.44	1592	3.47
	September	60 445	2.09	1358	2.96
	October	30 680	1.06	835	1.82
	November	14 060	0.48	402	0.87
	December	10 256	0.35	148	0.32
2022	January	477 423	16.52	647	1.41
	February	318 867	11.04	1354	2.95
	March	56 391	1.95	482	1.05
	April	28 615	0.99	122	0.26
	May	109 466	3.79	229	0.49
	June	90 606	3.13	360	0.78
	July	57 639	1.99	273	0.59
	August	33 202	1.14	19–2	0.41
	September	8156	0.29	87	0.18
	October	4187	0.14	35	0.07
	November	40 434	1.39	72	0.15
	December	92 805	3.21	252	0.55
Total		2 888 258	100.00	45 815	100.00

Source: Information extracted from the Coronavirus Panel on January 12, 2023, available at: <https://covid.saude.gov.br/>.AF: Absolute Frequency (n); RF: Relative Frequency (%)

In Paraná, the first cases were initially recorded in March 2020, with a total of 285 cases (0.009% of the total cases) and 6 deaths (0.01% of the total deaths). In this state, in 2020, the total confirmed cases and deaths due to COVID-19 were 444,475 and 9,312, respectively.

The months with the highest number of registered cases were August (2.03%), November (2.97%), and December (4.35%), while the months with the highest numbers of confirmed COVID-19 deaths were July (3.12%), August (3.42%), and December (5.07%).

In 2021, the total number of confirmed cases and deaths due to COVID-19 was 1,125,632 and 32,398, respectively. The months that stood out for cases and deaths were the same: March (6.00%), May (6.81%), and June (5.75%). Regarding deaths, throughout the period, the values were: 14.22%, 10.75%, and 11.88%, respectively.

Looking at the year 2022, the total number of confirmed cases and deaths due to COVID-19 was 1,318,151 and 4,105, respectively. Concerning cases, the months with the highest values were January (16.52%), February (11.04%), and May (3.79%). When considering deaths, emphasis is given to January (1.41%), February (2.95%), and March (1.05%).

Table 4 demonstrates the incidence, mortality, and lethality rates of COVID-19 in both states.

Table 4: Monthly distribution of mortality, lethality, and incidence rates of COVID-19 in the states of Rio Grande do Sul and Paraná, Brazil, from January 2020 to December 2022

YEAR	MONTHS	Rio Grande do Sul			Paraná		
		Mortality (100.000 hab.)	Case Fatality (100%)	Incidence (100.000 hab.)	Mortality (100.000 hab.)	Case Fatality (100%)	Incidence (100.000 hab.)
2020	January	0	0	0	0	0	0
	February	0	0	0.28	0	0	0
	March	0.03	0.31	11.07	0.05	2.10	2.46
	April	0.52	1.66	31.59	0.95	6.29	15.14
	May	1.59	1.78	89.12	1.08	2.68	40.27
	June	3.85	1.72	224.06	5.41	2.56	211.09
	July	12.18	2.43	499.78	12.42	2.48	501.07
	August	14.06	2.57	545.70	13.60	2.67	508.75
	September	11.22	2.65	422.96	10.77	2.50	429.24
	October	8.75	1.74	501.87	7.15	2.31	308.75
	November	10.22	0.95	1067.79	9.08	1.21	745.15
	December	18.49	1.71	1077.77	20.14	1.84	1090.33
	TOTAL	80.95	1.81	4472.03	80.70	2.095	3852.09
2021	January	15.52	1.90	815.38	17.14	1.66	1027.25
	February	17.89	1.70	1659.92	17.61	1.89	92953
	March	73.80	4.20	1753.25	56.15	375	1495.58
	April	39.62	4.68	846.45	38.91	4.36	890.88
	May	25.90	2.17	1191.77	42.46	2.50	1697.19
	June	25.29	2.76	916.09	46.90	3.27	1431.38
	July	14.83	3.62	409.00	22.62	3.61	625.76
	August	6.95	2.56	271.72	13.71	2.25	607.65
	September	5.38	2.31	233.02	11.70	2.24	520.88
	October	5.80	2.10	276.21	7.19	2.72	264.38
	November	5.19	3.21	161.84	3.46	2.85	121.16
	December	2.24	1.32	169.63	1.27	1.44	88.38
	TOTAL	238.46	2.73	8704.35	279.18	2.87	9700.08
2022	January	5.91	0.12	4883.36	5.54	0.13	4092.32
	February	12.48	0.60	2067.34	11.60	0.42	2733.23
	March	5.28	1.14	460.25	4.13	0.85	483.36
	April	1.70	0.53	321.80	1.04	0.42	245.27
	May	2.55	0.25	1006.16	1.96	0.20	938.31

Table 4: Monthly distribution of mortality, lethality, and incidence rates of COVID-19 in the states of Rio Grande do Sul and Paraná, Brazil, from January 2020 to December 2022

YEAR	MONTHS	Rio Grande do Sul			Paraná		
		Mortality (100.000 hab.)	Case Fatality (100%)	Incidence (100.000 hab.)	Mortality (100.000 hab.)	Case Fatality (100%)	Incidence (100.000 hab.)
	June	4.20	0.50	826.42	3.08	0.39	776.64
	July	3.7	0.48	765.39	2.34	0.47	494.06
	August	3.1	0.75	413.65	1.64	0.57	284.59
	September	1.56	1.88	83.23	0.74	1.02	72.99
	October	0.51	1.56	32.93	0.3	0.83	35.88
	November	0.62	0.18	344.44	0.61	0.17	346.58
	December	2.49	0.2	1191.26	2.16	0.27	795.49
	TOTAL	44.16	0.35	12 396.29	35.18	0.31	11 298.79
TOTAL OVERALL		363.59	1.42	25 572.68	395.07	1.586	24 850.98

When observing tables 4 and 5, it can be noted that concerning the entire analyzed period, the incidence in the state of Rio Grande do Sul had higher rates in 2020, with emphasis on December (1077.77), and in 2022, notably in January (4883.36). The state of Paraná surpassed only in 2021, with a highlight in May (1697.19).

Regarding mortality, the years remain similar to the incidence (figure 3), with the state of Rio Grande do Sul obtaining higher annual rates in 2020 and 2022, particularly in December (18.59) and February (12.48), respectively. Paraná, in 2021, stood out in mortality during March (56.15) (figure 4).

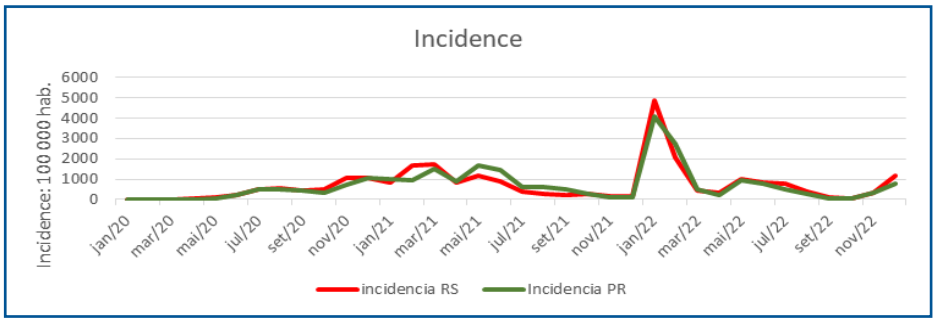

Figure 1: COVID-19 Incidence Rates in the States of Rio Grande do Sul and Paraná

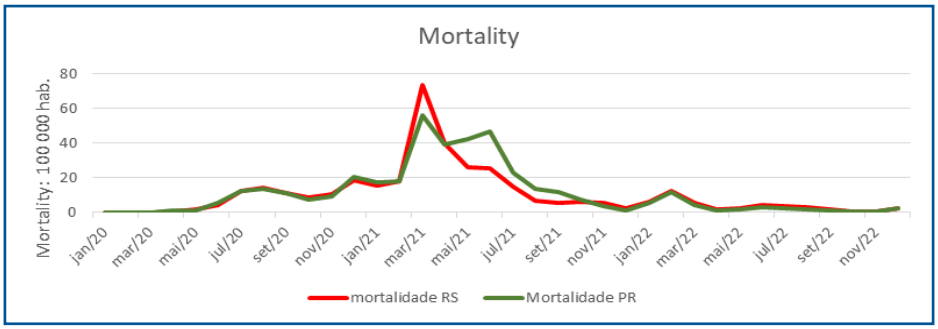

Figure 2: COVID-19 Mortality Rates in the States of Paraná and Rio Grande do Sul

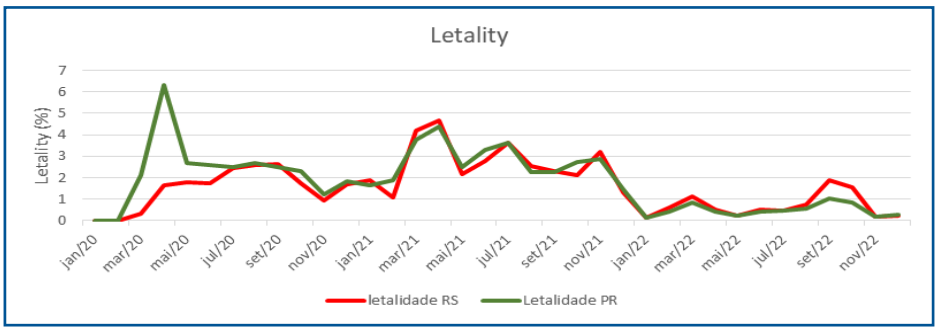

Figure 3: Graph of COVID-19 Fatality Rates in the States of Rio Grande do Sul and Paraná

In the aspect of fatality, it's noticed that the percentages were higher in 2020 and 2021 in the state of Paraná, highlighting the months of April (6.29 and 4.36) in the studied years. Rio Grande do Sul showed the highest fatality percentage, emphasizing the month of September (1.88%), as shown in figure 5.

When examining the entire period, it becomes apparent that Paraná surpasses Rio Grande do Sul across all categories, with values of 25,850.98 for incidence, 395.07 for mortality, and 1.58% for lethality.

The trends of mortality rates, lethality, and incidence of COVID-19 in the states of Rio Grande do Sul and Paraná can be visualized in Table 5. For analyses considered statistically significant ($p < 0.05$), the daily percentage change (DPC) reveals the percentage of daily change, indicating an increase or decrease for the variables.

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

RATE/YEAR	LINEAR REGRESSION				
	β	P	VPD	(IC95%)	Tendency
Rio Grande do Sul					
MORTALITY					
2020 to 2022	0.0002123	0.63	0.05	-0.15 ; 0.25	Stationary
2020	-0.0071697	<0.001	1.66	1.31 ; 2.02	Increasing
2021	-0.0033074	<0.001	-0.76	-1.02 ; -0.50	Decreasing
2022	-0.0022546	<0.001	-0.61	-0.82 ; -0.40	Decreasing
CASE FATALITY					
2020 to 2022	-0.0006079	<0.001	-0.14	-0.20 ; -0.08	Decreasing
2020	-0.0002408	0.305	-0.06	-0.16 ; 0.05	Stationary
2021	-0.0002838	0.473	-0.07	-0.24 ; 0.11	Stationary
2022	0.001096	0.107	0.25	-0.05 ; 0.56	Stationary
INCIDENCE					
2020 to 2022	0.0009663	0.122	0.22	-0.06 ; 0.51	Stationary
2020	0.0073262	<0.001	1.70	1.31 ; 2.09	Increasing
2021	-0.0028033	<0.001	-0.64	-0.85 ; -0.43	Decreasing
2022	-0.0020065	0.295	-0.46	-1.32 ; 0.41	Stationary

β - Regression coefficient; P - p-value; DPD - Daily Percentual Variation; C95% - 95% confidence interval.*Statistical difference detected by the Prais-Winsten regression test, p<0.05.

Table 6: Prais-Winsten regression estimates and daily percentual variation (DPV) of COVID-19 mortality, fatality, and incidence rates in the state of Paraná, Brazil, from January 2020 to December 2022

RATE/YEAR	LINEAR REGRESSION				
	β	P	β	(IC95%)	β
Paraná					
MORTALITY					
2020 to 2022	-0.000557	0.119	-0.13	-0.29 ; 0.03	Stationary
2020	0.0060981	<0.001	1.41	1.04 ; 1.79	Increasing
2021	-0.0035531	<0.001	-0.81	-1.13 ; -0.50	Decreasing
2022	-0.0026543	<0.001	-0.61	-0.61 ; -0.84	Decreasing
CASE FATALITY					
2020 to 2022	-0.0010223	<0.001	-0.24	-0.28 ; -0.19	Decreasing
2020	-0.0019057	<0.001	-0.44	-0.56 ; -0.31	Decreasing
2021	-0.0001992	0.351	-0.05	-0.14 ; 0.05	Stationary
2022	0.0008202	0.069	0.19	-0.01 ; 0.39	Stationary
INCIDENCE					
2020 to 2022	0.0016438	0.001	0.38	0.16 ; 0.60	Increasing
2020	0.0118071	<0.001	2.76	1.94 ; 3.58	Increasing
2021	-0.0033085	<0.001	-0.76	-0.94 ; -0.58	Decreasing
2022	-0.0030327	<0.001	-0.70	-1.08 ; -0.31	Decreasing

β - Regression coefficient; P - p-value; DPD - Daily Percentual Variation; C95% - 95% confidence interval. *Statistical difference detected by the Prais-Winsten regression test, p<0.05.

For the state of Rio Grande do Sul, it can be observed that the incidence trend was increasing in 2020 and decreasing in 2021 ($p<0.05$). Regarding mortality, it showed an increasing trend in 2020 and decreasing trends in 2021 and 2022 ($p<0.05$). When examining fatality rates, it was noted that the trend for the entire period was decreasing ($p<0.05$).

In Paraná, the incidence was increasing in 2020 and for the entire period, while it decreased in 2021 and 2022 ($p<0.05$). Mortality increased in 2020 and decreased in 2021 and 2022 ($p<0.05$). It can be observed that fatality rates had a decreasing trend in 2020 and for the entire period analyzed, from 2020 to 2022 ($p<0.05$).

DISCUSSION

The analysis of COVID-19 data spanning from 2020 to 2022 in the Brazilian states of Rio Grande do Sul and Paraná reveals distinctive patterns in incidence, mortality, and fatality rates (tables 2 and 3). In Rio Grande do Sul, with 2,927,909 reported cases and 41,594 confirmed deaths, the temporal distribution indicates a surge in cases during specific months in 2020 and 2022, notably in December and January, while mortality rates experienced fluctuations throughout the study period. In contrast, Paraná, with 2,888,258 cases and 45,815 deaths, exhibited a consistent increase in incidence during 2020 and a subsequent decline in 2021 and 2022 (tables 4 and 5). The fatality rates in Paraná were notably higher in 2020 and 2021, particularly in April, compared to Rio Grande do Sul. Examining the monthly distribution of cases and deaths in both states highlights the dynamic nature of the pandemic (figure 1). In Rio Grande do Sul, the onset of COVID-19 cases in February 2020 marked a subsequent rise, peaking in August, November, and December of that year.

Deaths mirrored this trend, reaching peaks in July, August, and December 2020. The year 2021 witnessed increased cases in February, March, and May, while deaths peaked in March, April, and May. In 2022, both cases and deaths were elevated in January, February, and December (figures 2 and 3). Paraná exhibited a similar trend, with notable peaks in cases and deaths during specific months in 2020, 2021, and 2022.

Comparing the states, Rio Grande do Sul demonstrated higher incidence rates in 2020 and 2022, while Paraná surpassed only in 2021. Mortality rates followed a similar pattern, with Rio Grande do Sul leading in 2020 and 2022, while Paraná exhibited higher rates in 2021. Fatality percentages were notably higher in Paraná during 2020 and 2021, particularly in April, while Rio Grande do Sul exhibited the highest fatality percentage in September (figure 5). These findings underscore the importance of continuous monitoring and targeted interventions to address the evolving dynamics of the COVID-19 pandemic in these regions.

Understanding the behavior of the COVID-19 pandemic is associated with a detailed analysis of its mortality spread rate, fatality, incidence, and factors impacting these indicators. Therefore, it's crucial for informing decisions and implementing measures to combat the virus's spread. Throughout the study period, it was observed that Paraná surpasses Rio Grande do Sul in all categories, with higher values of incidence, mortality, and fatality.

At the beginning of the pandemic, from February to April 2020, the state of Paraná exhibited a significantly higher fatality rate compared to Rio Grande do Sul. This occurrence might be related to delayed disease prevention protocols and the population's non-adherence to non-pharmacological methods for preventing COVID-19.

The first Law No. 20189 regarding preventive measures in Paraná was enacted on April 28, 2020[19]. In comparison, in Rio Grande do Sul, preventive measures (Law No. 55.154) were instituted on April 1, 2020[12].

However, when providing a comparison between the epidemiological outcomes of the state of São Paulo, which enacted decree No. 55.154 on March 20, 2020[20], there seems to be a causal relationship regarding the political decision-making of implementing non-pharmacological policies and restrictions on people, which were implemented later in the state of Paraná at the onset of the pandemic.

This situation of analyzing the implementation date of public policies to control the COVID-19 pandemic, especially during the period of widespread circulation of the delta variant of Sars-CoV-2[21], indicates a delay in the population's adherence to behavioral measures and in the reopening of commerce, influencing the control of SARS-CoV-2 dissemination in the state of Paraná.

The study by Klokner *et al.* (2021)[22] analyzed the epidemiological profile and risk and protective variables for COVID-19 in the southern region of Brazil, composed of the states of Rio Grande do Sul, Paraná, and Santa Catarina. There was a trend in the three states of an increase in cases up to the sixteenth epidemiological week. From this point, the incidence rates in Santa Catarina progressed compared to the other states until the twenty-second epidemiological week when the trend of declining prevalence and incidence rates intensified in all three states, indicating greater effectiveness in social distancing policies.

During the analyzed period, the incidence in the state of Rio Grande do Sul showed higher rates in 2020, notably in December, and in 2022, particularly in January, whereas the state of Paraná was superior only in 2021, emphasizing the month of May.

Studies indicate that the socioeconomic context is decisive in greater vulnerability to COVID-19[23,24]. The population in situations of social vulnerability is most affected by the pandemic's impacts due to the lack or insufficiency of resources, prevention strategies, and disease treatment in their daily lives, along with difficulties in practicing social distancing and maintaining employment and income. Moreover, they have reduced access to health services and basic sanitation. Hence, it is crucial to consider this scenario of social vulnerability when developing actions for health promotion, prevention, and control of COVID-19[25].

Thus, the pandemic's impact resonates across the economy, politics, and society, highlighting the need for attention to conditions that increase population vulnerability[26].

The Brazilian territory is marked by inequality and

inequities in access to and ownership of goods, services, and wealth, which are unevenly distributed. In the context of health, these inequalities result in significant disparities in access to technological advancements and opportunities for exposure to health determinants. Consequently, there is a rapid increase in the number of cases and mortality rates in peripheral regions of cities. In these areas, unfavorable living conditions and limited healthcare resources may contribute to a more adverse scenario in facing the pandemic and its consequences[24,27].

This relationship between the pandemic and social vulnerability has also occurred in other instances, such as the Spanish flu and H1N1, demonstrating that social inequalities are determinants for the transmission and severity of these diseases[28].

One of the indices that measures the degree of concentration of per capita household income distribution in a specific population and geographic area is the Gini Index, where the closer it is to one, the higher the inequality[28]. In 2021, Paraná presented a Gini Index of 0.475, indicating higher inequality compared to Rio Grande do Sul, which was 0.468[14].

Supporting studies that relate higher COVID-19 mortality rates in regions with greater social inequalities[29,30], the State of Paraná showed higher mortality rates compared to Rio Grande do Sul.

Furthermore, the results indicated a similar behavior between mortality and incidence. Rio Grande do Sul exhibited higher total annual rates in 2020 and 2022, highlighting December and February, respectively. In contrast, Paraná emphasized 2021, notably March.

The lethality of COVID-19 is influenced by intrinsic characteristics of infected individuals, such as age, pre-existing medical conditions, and lifestyle, as well as the availability of therapeutic resources like hospital beds, healthcare teams, ventilators, and medications. Therefore, when analyzing lethality, it's crucial to consider this combination of factors that may impact the disease outcome. An integrated approach to these variables is crucial for a comprehensive understanding of COVID-19 lethality patterns and to assist in formulating effective prevention and control strategies[31-33].

In Paraná, although indigenous patients represented the lowest percentage of hospitalizations compared to other groups, they exhibited the highest lethality rate in comparison with other races, with nearly half of the indigenous patients admitted resulting in death[13]. The low number of affected individuals might be attributed to the isolation this group maintains from urban environments, which limits virus transmission.

Lethality rates were higher in 2020 and 2021 in the state of Paraná, emphasizing April in both years. In 2022, Rio Grande do Sul had the highest lethality percentage, particularly in September. When considering the total period, the state of Paraná presented a higher lethality index compared to Rio Grande do Sul.

Furthermore, it's worth noting that the southern region states have significant determinants capable of influencing COVID-19 mortality, incidence, and lethality rates. These states exhibit higher aging indices in Brazil[34], have the highest historical incidence of severe acute respiratory syndrome, and possess a fragile public healthcare network, although more structured than in other regions of the country, such as the Northeast[32].

Overall, the incidence trend was increasing in 2020 and decreasing in 2021. Mortality showed an increase in 2020 and decreased in 2021 and 2022; conversely, lethality exhibited a decreasing trend throughout the entire studied period.

In the state of Paraná, a continuous rise in COVID-19 case incidence was observed throughout the analyzed period. Regarding mortality, there was an increase in 2020 and a decrease in the years 2021 and 2022. As for lethality, compared to the initial period in 2020, there was a trend of reduction that persisted throughout the entire analysis.

In the state of Rio Grande do Sul, distinct trends were identified concerning COVID-19 pandemic indicators. The incidence of cases showed an increase in 2020 but experienced a decline in 2021. Regarding mortality, there was a rise in 2020; however, subsequent years, both in 2021 and 2022, witnessed a decrease. Finally, when analyzing lethality, it was observed that its trend throughout the entire period was decreasing.

These data indicate a favorable evolution in pandemic control within the state, with a decrease in mortality and lethality rates despite the rise in confirmed cases. It's crucial to continue monitoring the indicators to track the epidemiological scenario and ensure the effectiveness of the prevention and control measures adopted.

Findings by Paiva *et al.* (2020)[21] reported that urbanization changes in Rio Grande do Sul were associated with the incidence rate of COVID-19 cases. Urbanization is linked to industrialization and job generation, but this process has led to disorderly occupation of urban spaces, affecting people's lifestyles, including difficulties in accessing healthcare services and basic hygiene conditions.

Regarding urban infrastructure and urban transit in processes related to goods acquisition and service production, increased physical contact between individuals facilitated virus spread[35,36].

Additionally, the high density observed in large cities facilitated the rapid spread of the disease[35] as the likelihood of contact between individuals was higher. Another ecological study confirmed the hypothesis that urbanization and the Municipal Human Development Index (IDHM) are social indicators related to the occurrence of COVID-19 cases in municipalities in Paraná[21].

This situation is cause for concern as mentioned by Abreu[37], the virus might encounter a population that has already suffered from the pandemic's consequences and has limited resources in terms of education and healthcare. This could facilitate virus dissemination, contributing to the ongoing development of COVID-19 and potentially triggering new waves of the disease.

Despite the advancement of vaccination, it's essential to adopt adequate prevention, control, and social support measures to mitigate these effects and comprehensively protect public health. Furthermore, the importance of promoting non-pharmacological measures, such as double mask use, alongside personal hygiene practices like handwashing, is emphasized[37].

Therefore, it is essential to develop intervention strategies to reduce the impacts of endemic diseases, even within the context of COVID-19. However, it's crucial that while coordinating Public Policies during a syndemic, health indicators for various infectious diseases should be monitored. This consideration involves recognizing that an intervention against one disease can negatively impact another38.

Minimizing the impacts of the COVID-19 pandemic is only possible through a scientifically evidenced-based plan for containing infectious diseases. This plan should consider the specificities and particularities of the region in question. Consequently, policymakers must remain vigilant, continuously monitor COVID-19 data, and adapt interventions while considering all stakeholders, including communities[34].

The information regarding time series related to COVID-19 incidence, mortality, and lethality is still scarce in the literature, especially concerning Brazilian states, particularly in the southern region. Similar studies aim to bring robustness to the existing knowledge, enabling a deeper understanding of this scenario. Consequently, these efforts seek to provide new analytical epidemiological perspectives for the public healthcare system[33,39,40].

The study was conducted through the analysis of publicly accessible population data obtained from an official source. However, it's important to consider that this database is continually updated, implying that the results might undergo future variations due to corrections made in the records. Additionally, the data could be subject to underreporting of cases and deaths, affecting the accuracy of the information presented.

The number of accumulated COVID-19 cases could be higher than those recorded in the database as the number of specific tests for the disease was limited over the three years of the pandemic's duration. Not all symptomatic individuals were tested. However, in this ecological study, these variations do not introduce biases in interpreting the results, allowing for a depiction of the three-year evolution of the pandemic in the states of Paraná and Rio Grande do Sul, in the Southern region of Brazil.

Therefore, time series analysis allows the dataset, with the available/possible observations for analysis, to represent one trajectory among many that could have been observed. Just as in the analysis of disease incidence (such as in the case of COVID-19) as an ecological indicator over time, this is an expression of reality because incidence on a particular day/month or year is generally correlated with the occurrence on the preceding day/month/year. This correlation is expressed in an autocorrelation function. Thus, the limitations of the study are inherent to the current analytical process for a comprehensive understanding of the pandemic's evolution in the present scenario.

CONCLUSION

This research highlights the regional heterogeneity and disparities in incidence, mortality, and lethality, with Paraná facing more significant challenges compared to Rio Grande do Sul. These insights carry crucial implications for the development of targeted public health strategies and decision-making to effectively mitigate the impacts of COVID-19 in these specific regions.

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Resumo

Introdução: a doença do novo Coronavírus (COVID-19) é causada pelo SARS-CoV-2 e representa o agente causador de uma doença respiratória e metabólica com alto índice de fatalidade e continua sendo um problema de saúde pública nos dias atuais. Houve o agravamento das desigualdades sociais vividas no Brasil e no mundo. Notadamente, a ausência de um sistema de saúde consolidado e universal contribuiu para o aumento das desigualdades e oportunidades de sobrevida daqueles acometidos com a infecção do SARs-CoV2 e manifestação da COVID-19. A região sul se tornou a segunda região com maior número de casos no Brasil.

Objetivo: avaliar os desfechos epidemiológicos da incidência, letalidade e mortalidade entre os estados do Rio Grande do Sul e Paraná, na região Sul brasileira.

Método: foi realizado um estudo ecológico de séries temporais utilizando dados secundários oficiais de divulgação pública governamental casos e mortes por COVID-19 do painel da Secretaria Estadual de Saúde dos estados de Rio Grande do Sul e Paraná. As séries temporais foram construídas aplicando o modelo de regressão de Prais-Winsten. As análises estatísticas foram realizadas com o uso do software STATA 14.0.

Resultados: Verificou-se que para o estado do Rio Grande do Sul as tendências em relação à incidência foram crescentes no ano de 2020 e decrescente no ano de 2021 ($p<0,05$). Já em relação a mortalidade foi crescente em 2020 e decrescente em 2021 e 2022 ($p<0,05$). Quando verificou-se a letalidade, foi observado que a tendência para o período inteiro foi decrescente ($p<0,05$). Em relação ao Paraná a incidência foi crescente no ano de 2020 e no período inteiro enquanto foi decrescente no ano de 2021 e 2022 ($p<0,05$). Já a mortalidade foi estacionaria no ano de 2020 e decrescente no ano de 2021 e 2022 ($p<0,05$).

Conclusão: A pandemia da COVID-19 é um grave problema de saúde pública nos estados do paraná e Rio Grande do Sul. O estado do Paraná apresentou um quadro de maior gravidade nos desfechos epidemiológico, em comparação ao estado do Rio Grande do Sul.

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

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