

ORIGINAL ARTICLE

# Three years of the COVID-19 pandemic: a comparative analysis of incidence, case fatality, and mortality among the States in the Southern Region of Brazil

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**Abstract**

**Introduction:** the first COVID-19 case in Brazil was confirmed on February 26, 2020. As of March 17, 2023, the Ministry of Health reported 699,634 deaths from COVID-19, with a case fatality rate of 1.9%. The impact of the COVID-19 pandemic in Brazil extends to socioeconomic and healthcare systems, reflecting significant regional disparities.

**Objective:** To analyze mortality, incidence, and case fatality rates for COVID-19 in the states of Paraná and Santa Catarina, in the southern region of Brazil.

**Methods:** This is an ecological time-series study using official Brazilian secondary data for COVID-19 cases and deaths. Data were extracted from the dashboard of the State Health Department of Santa Catarina and Paraná. Temporal series were developed for trend analysis using the Prais-Winsten regression model. Statistical analyses were performed using STATA 14.0 software (College Station, TX, USA, 2013).

**Results:** In the analysis of rates over the entire period, trends for mortality, case fatality, and incidence in the state of Santa Catarina are decreasing, decreasing, and stationary, respectively. In Paraná, rates over the entire period showed a stationary trend for mortality, decreasing for case fatality, and increasing for incidence.

**Conclusion:** COVID-19 had a devastating effect on the states of Santa Catarina and Paraná. Both states experienced the progression of the COVID-19 pandemic, with higher case fatality and mortality rates observed in Paraná, while Santa Catarina had a higher incidence rate over the three years of the COVID-19 pandemic.

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

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## Authors summary

### Why was this study done?

This study was conducted to analyze and compare the outcomes of the COVID-19 pandemic in the states of Paraná and Santa Catarina, in the southern region of Brazil. The aim was to understand how socio-economic, demographic, and health factors influenced the incidence, mortality, and case fatality rates of COVID-19 in these states. The research sought to provide valuable insights for policymakers and healthcare professionals, facilitating informed decision-making on prevention, control, and treatment strategies for the disease. Additionally, it underscored the importance of mass vaccination as an effective implement in pandemic containment.

### What did the researchers do and find?

The researchers conducted a study to analyze and compare the outcomes of the COVID-19 pandemic in the states of Paraná and Santa Catarina, in the southern region of Brazil. They examined socio-economic, demographic, and health factors such as population density, age distribution, socio-economic inequalities, and social indicators to understand how these elements influenced the incidence, mortality, and case fatality rates of COVID-19 in both states. The results revealed that Paraná had higher case fatality and mortality rates, while Santa Catarina had a higher incidence rate. Mass vaccination was identified as a crucial factor in reducing severe cases and deaths from COVID-19 in both states. Therefore, the researchers emphasized the ongoing importance of epidemiological surveillance and the adaptation of public policies to address the pandemic.

### What do these findings mean?

The findings mean that socio-economic, demographic, and health factors have a substantial impact on the outcomes of the COVID-19 pandemic in different regions. In the specific case of the states of Paraná and Santa Catarina in the southern region of Brazil, the results indicate that Paraná faced more significant challenges in terms of mortality and case fatality, while Santa Catarina had a higher incidence of cases. Mass vaccination was highlighted as an effective strategy in reducing severe cases and deaths. This emphasizes the ongoing importance of evidence-based public policies, epidemiological surveillance, and preventive health measures to control and mitigate the effects of the pandemic. Additionally, the results highlight the need to consider the socio-economic and demographic specificities of each region when planning and implementing pandemic response strategies.

### Highlights

The study presents a novel analysis of the evolution of COVID-19 in the states of Paraná and Santa Catarina, both located in the southern region of Brazil. Using an ecological time series study method, researchers investigated trends in mortality, case fatality, and incidence over the analyzed period. The results reveal significant disparities between the states, with Santa Catarina showing decreasing trends in all rates, while Paraná exhibits variations, particularly higher case fatality and mortality rates. This approach allows a unique insight into the pandemic's impact in these regions, contributing to a deeper understanding of the dynamics of COVID-19 in the Brazilian regional context.

## INTRODUCTION

COVID-19, caused by the SARS-CoV-2 virus, has emerged as a significant threat to global health<sup>1</sup>. Since its initial identification in Wuhan, China, in December 2019, COVID-19 has spread worldwide, resulting in a devastating impact on public health and the economy<sup>1</sup>. As of March 29, 2023, there have been over 761 million confirmed cases and more than 6.8 million deaths worldwide, with Europe alone accounting for over 2.2 million deaths<sup>2</sup>.

On January 7, 2020, Chinese authorities confirmed the emergence of a new disease caused by a virus belonging to the Coronaviridae family. The SARS-CoV-2 strain was classified as a betacoronavirus<sup>3</sup>. The novel coronavirus showed similarities to other coronaviruses in its family, with severity ranging from asymptomatic cases to serious cases developing Severe Acute Respiratory Syndrome (SARS).

The disease spread exponentially, leading the World Health Organization (WHO) to declare a global emergency on January 30, 2020, and later, on March 11 of the same year, declaring it a pandemic<sup>3</sup>. The unprecedented spread of the disease put the world on high alert, causing significant impacts on both, the healthcare system and the global economy.

Researchers, scientists, and medical communities mobilized to understand the virus's origin, mode of transmission and unique characteristics, particularly its rapid spread and high contagion capacity, raising concerns about healthcare system overload<sup>4</sup>.

The primary mode of transmission includes direct contact with respiratory droplets from infected individuals through coughing and/or sneezing. Additionally, studies

suggest the potential airborne transmission of the virus through aerosols, although there is no experimental evidence proving long-range aerosol transmission in COVID-19 infection<sup>5</sup>.

The first COVID-19 case in Brazil was confirmed on February 26, 2020, involving a 61-year-old man who had come from Italy. Just 48 hours after the first case confirmation in the country, a team of Brazilian researchers announced the complete sequencing of the novel coronavirus. The pandemic was declared on March 11, 2020, and the first COVID-19 death in Brazil occurred on March 12, 2020. As of March 17, 2023, the Ministry of Health reported 699,634 deaths from COVID-19 in Brazil, with a case fatality rate of 1.9%<sup>6</sup>.

Clinical outcomes of COVID-19 vary among individuals and are influenced by factors such as age, gender, ethnicity and underlying health conditions<sup>7</sup>. Symptom presentation ranges from asymptomatic cases to severe, life-threatening complications<sup>7</sup>. Older adults, individuals with pre-existing health problems and those with weakened immune system are more vulnerable to severe infections and associated mortality<sup>7,8</sup>.

Brazil presents a complex epidemiological scenario with significant regional differences due to its vast continental dimensions, climate variations, vegetation, cultural diversity, and socioeconomic factors. The Ministry of Health urged all states and municipalities to adopt non-pharmacological interventions promoting social distancing and avoiding gatherings, as recommended by the WHO<sup>9</sup>.

In the southern region of Brazil, COVID-19 initially appeared in the state capitals, spreading through

major highways, with a higher disease projection in Santa Catarina and a lower one in Rio Grande do Sul<sup>10</sup>.

Santa Catarina, bordering the states of Paraná and Rio Grande do Sul, has a subtropical climate, occasional snowfall in winter, especially in mountainous regions, and a high Human Development Index (HDI). Its economy is dominated by the agro-industrial, mechanical, textile, and tourism sectors, forming a robust and dynamic economy<sup>11</sup>.

In Santa Catarina, the first two COVID-19 cases were confirmed on March 12, 2020, both in Florianópolis, with patients from New York and the Netherlands. The first death was confirmed on March 26, 2020, in São José, Greater Florianópolis<sup>12</sup>. The surge in cases led to the approval of new decrees establishing stricter measures to curb the virus's spread<sup>13</sup>.

Paraná, one of the most developed states in Brazil, has a culture influenced by immigrants of strong European descent. It has a subtropical climate with rainfall and mild temperatures throughout the year. The state's economy is based on agriculture and industry (food, automotive, and electronics), as well as a thriving tourism sector. Also, Paraná boasts suitable logistical infrastructure, including a vast network of railways, maritime and river ports, and highways, along with the Itaipu Dam<sup>11</sup>.

In Paraná, the first six COVID-19 cases were reported on 12 March 2020, five in Curitiba and one in Cianorte, in the northwest of the state, with the first deaths

occurring on 25 March 2020. According to the Health Department's report, the year with the highest number of cases in Paraná was 2021, totaling 32,234 deaths. This period was known as the 'second wave' of the pandemic, during which the delta strain predominated worldwide<sup>14,15</sup>.

The impact of the COVID-19 pandemic on Brazil's socio-economic and health systems, as well as the significant regional disparities and the high number of cases and deaths in Santa Catarina and Paraná, this study aimed to analyze the mortality, incidence, and fatality of COVID-19 in these states.

## METHODS

### Study Design and Location

This study adopts an ecological and time-series design, following the protocol by Abreu, Emulsharaf, and Siqueira<sup>16</sup>. Official data on COVID-19 cases and deaths from the states of Santa Catarina and Paraná were analyzed.

Public data are available on the website <https://www.saude.pr.gov.br/Pagina/Coronavirus-COVID-19> for the state of Paraná, and for Santa Catarina, information was extracted from <https://www.saude.pr.gov.br/Pagina/Coronavirus-COVID-19> and <https://dados.sc.gov.br/dataset/covid-19-dados-anonimizados-de-casos-confirmados/resource/76d6dfe8-7fe9-45c1-95f4-cab971803d49> respectively.

**Table 1:** Sociodemographic characteristics of the State of Santa Catarina and Paraná, 2023

Sociodemographic characteristics	Santa Catarina	Paraná
Region *	South	South
Number of municipalities *	295	284
State Capital *	Florianópolis	Curitiba
Territorial extension * (2022)	95,730.690 km <sup>2</sup>	199,298,981 km <sup>2</sup>
Estimated Population (2021)	7,338,473 people	11,597,484 people
Demographic density * (last census, 2010)	65.29 inhabitants/km <sup>2</sup>	52.40 inhabitants/km <sup>2</sup>
Urban household situation (2010)*	5,247,913 people	8,912,692 people
Rural household situation (2010)*	1,000,523 people	1,531,834 people
Monthly household income per capita *	R\$ 2,018	R\$ 1,846
Human Development Index (HDI) (last census, 2010) *	0.774	0.749
Number of Basic Health Units of the Unified Health System (SUS) (2009) *	2,856 establishments	4,091 establishments
outpatient SUS*	2,136 establishments	3,307 establishments
SUS dialysis*	42 establishments	69 establishments
SUS emergency*	254 establishments	446 establishments
SUS hospitalization*	194 establishments	411 establishments
SUS ICU*	42 establishments	76 establishments
Number of beds for hospitalization in healthcare establishments (2009)*	15,557 beds	26,793 beds
Public*	3,509 beds	6,512 beds
Private*	12,048 beds	20,281 beds

Source: \*Brazilian Institute of Geography and Statistics<sup>11</sup>.

### Sampling and Eligibility Criteria

All cases and deaths from COVID-19 from 2020 to 2022 were included. Occurrences were confirmed through laboratory, clinical, and clinical-epidemiological diagnosis. 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 not identified”<sup>17</sup>.

Deaths and cases were classified by the date of symptom onset, and cases without information on notification or death date were excluded from the study. We organized and tabulated this data in Excel, subsequently, 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 was described in terms of 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 case fatality rate (%) were calculated as described below:

$$(1) \text{ Incidence: } \frac{\text{number of cases}}{\text{population}} \times 100.000$$

$$(2) \text{ Mortality: } \frac{\text{number of deaths}}{\text{population}} \times 100.000$$

$$(3) \text{ Case fatality: } \frac{\text{number of deaths}}{\text{number of cases}} \times 100.000$$

For population, the population projection for each state from 2000-2030 was considered. For Santa Catarina, the estimated population for the years 2020 (8,628,901 inhabitants), 2021 (8,710,364 inhabitants) and 2022 (8,789,130 inhabitants) was used. In the case of Paraná, the estimated population for the years 2020 (11,516,840 inhabitants), 2021 (11,597,484 inhabitants), and 2022 (11,443,208 inhabitants) was utilized<sup>11</sup>.

To analyze the trend, the protocol of Antunes and Cardoso<sup>18</sup> was employed. Time series were constructed using the Prais-Winsten regression model<sup>19</sup>.

Time series are widely used in public health and epidemiology to analyze and predict the incidence of diseases over time, such as in the case of COVID-19, identifying patterns and seasonal trends of the disease.

The identification of seasonal trends of COVID-19 in a time series analysis allows for an assessment of the comprehensive view of the disease waves over the analyzed period. Moreover, this epidemiological measure enables real-time monitoring of COVID-19 outbreaks,

contribute to immediate action by health authorities to implement effective control measures. Another application of time series is to assess the effectiveness of preventive interventions (such as mask-wearing, vaccination, booster doses, and social distancing measures).

Time series have allowed researchers and healthcare professionals to monitor and respond to disease outbreaks, predict disease incidence, identify seasonal trends, and assess the effectiveness of disease prevention and control interventions, as in the case of the COVID-19 pandemic.

Additionally, by using the Prais-Winsten regression model, first-order autocorrelation was allowed to analyze the values of time series and facilitate the assessment and classification of incidence, mortality and case fatality as increasing, decreasing, or stationary<sup>19</sup>. Trends were classified as stationary when the p-value was not significant ( $p > 0.05$ )<sup>18</sup>.

The probability values (p) and daily percent change (DPC), considering a significance level of 95%, were calculated using the equations, where  $\beta$  is the angular coefficient of linear regression,  $ul$  (index) is the upper limit, and  $ll$  (index) 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, a two-tailed z-test was utilized, considering differences with a p-value  $< 0.05$  as significant<sup>18</sup>.

The statistical analyses were conducted using STATA 14.0 software (College Station, TX, USA, 2013).

### Ethical Aspects

The data obtained from the information systems maintained by the Ministry of Health are deemed reliable, enabling their use as a feasible tool for analyzing COVID-19 epidemiological indicators<sup>19</sup>. As these are public data with broad accessibility, it was not necessary to seek approval from the Scientific Research Ethics Committee (CEP) for the study.

## RESULTS

In the state of Santa Catarina, events related to the COVID-19 pandemic were recorded from January 2020 to December 2022., with a total of 1,972,219 confirmed cases and 22,636 deaths due to COVID-19. Table 2 shows the monthly distribution of confirmed COVID-19 cases and deaths in Santa Catarina from 2020 to 2022.

In the state of Paraná, between January 2020 and December 2022, a total of 2,888,258 cases and 45,815 deaths have been registered due to COVID-19. The monthly distribution of confirmed COVID-19 cases and deaths in the state of Paraná can be observed in Table 3.

**Table 2:** Monthly distribution of cases and deaths confirmed by COVID-19 in the state of Santa Catarina, Brazil, from January 2020 to December 2022

Year	Month	Confirmed cases		Confirmed deaths	
		Frequency absolute (n)	Frequency relative (%)	Frequency absolute (n)	Frequency relative (%)
2020	January	0	0	0	0
	February	81	0.004	0	0
	March	1789	0.090	6	0.026
	April	3268	0.165	50	0.220
	May	10 313	0.522	97	0.428
	June	34 205	1,734	230	1,016
	July	<b>92 731</b>	<b>4,701</b>	<b>901</b>	<b>3,980</b>
	August	53 654	2,720	<b>1061</b>	<b>4,687</b>
	September	29 830	1,512	516	2,279
	October	57 199	2,900	329	1,453
	November	<b>148 243</b>	<b>7,516</b>	711	3,141
	December	<b>105 691</b>	<b>5,358</b>	<b>1509</b>	<b>6,666</b>
2021	January	80 477	4,080	1110	4,903
	February	<b>120 048</b>	<b>6,086</b>	1128	4,983
	March	<b>130 024</b>	<b>6,592</b>	<b>3723</b>	<b>16,447</b>
	April	75 662	3,836	2480	10,955
	May	84 374	4,278	1728	7,633
	June	77 234	3,916	1521	6,719
	July	51 049	2,588	1083	4,784
	August	38 852	1,969	698	3,083
	September	27 805	1,409	528	2,332
	October	20 904	1,059	380	1,678
	November	13 382	0.678	298	1,316
	December	15 640	0.793	182	0.804
2022	January	<b>337 542</b>	<b>17,114</b>	<b>493</b>	<b>2,177</b>
	February	<b>109 693</b>	<b>5,561</b>	<b>759</b>	<b>3,353</b>
	March	16 336	0.828	<b>243</b>	<b>1,073</b>
	April	13 118	0.665	65	0.287
	May	41 578	2,108	78	0.344
	June	<b>46 277</b>	<b>2,346</b>	169	0.746
	July	36 979	1,874	208	0.918
	August	12 769	0.647	111	0.490
	September	3502	0.177	41	0.181
	October	3309	0.167	12	0.053
	November	36 433	1,847	56	0.247
	December	42 228	2,141	132	0.583
<b>Total</b>		<b>1 972 219</b>	100.00	<b>22 636</b>	100.00

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

In the state of Santa Catarina, the first confirmed cases of COVID-19 were recorded in February 2020, representing 0.004% of the total number of cases during the period analysed. For deaths, the first records appeared in April of the same year, corresponding to a relative frequency of 0.96% of the deaths.

In 2020, the average number of confirmed COVID-19 cases and deaths in Santa Catarina was 44,750.3 and 450.8, respectively. The months with the highest number of confirmed COVID-19 cases were July (4.70%), November (7.51%), and December (5.35%). Regarding confirmed COVID-19 deaths, the standout months were

July (3.98%), August (4.68%), and December (6.66%).

Continuing into the pandemic period, the average number of confirmed COVID-19 cases and deaths in 2021 was 58,313.7 and 197.25, respectively. Noteworthy months for confirmed cases were February, March, and May, accounting for 6.08%, 6.59%, and 4.27%, respectively. Concerning the total number of deaths in this year, standout months were March, April, and May, representing 16.44%, 10.95%, and 7.63% of the total deaths.

In the year 2022, the average number of confirmed COVID-19 cases and deaths was 19,588.92 and 155.41, respectively. January stood out with 17.11% of the total cases, followed by February with 5.56% and June with 2.34%. In the case of deaths, the standout months were January, February, and March, with relative frequencies of deaths equivalent to 2.17%, 3.35%, and 1.07%, respectively.

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

Year	Month	Confirmed cases		Confirmed deaths	
		Frequency absolute (n)	Frequency relative (%)	Frequency absolute (n)	Frequency relative (%)
2020	January	0	0	0	0
	February	0	0	0	0
	March	285	0.009	6	0.013
	April	1747	0.060	110	0.240
	May	4647	0.160	125	0.272
	June	24 357	0.843	625	1,364
	July	57 817	2,001	<b>1434</b>	<b>3,129</b>
	August	<b>58 679</b>	<b>2,031</b>	<b>1570</b>	<b>3,426</b>
	September	49 528	1,714	1243	2,713
	October	35 626	1,233	826	1,802
	November	<b>85 980</b>	<b>2,976</b>	1048	2,287
	December	<b>125,809</b>	<b>4,355</b>	<b>2325</b>	<b>5,074</b>
2021	January	119 206	4,127	1990	4,343
	February	107 867	3,734	2044	4,461
	March	<b>173 553</b>	<b>6,008</b>	<b>6517</b>	<b>14,224</b>
	April	103 382	3,579	4516	9,857
	May	<b>196 949</b>	<b>6,818</b>	<b>4928</b>	<b>10,756</b>
	June	<b>166 103</b>	<b>5,750</b>	<b>5443</b>	<b>11,880</b>
	July	72 616	2,514	2625	5,729
	August	70 515	2,441	1592	3,474
	September	60 445	2,092	1358	2,964
	October	30 680	1,062	835	1,822
	November	14 060	0.486	402	0.877
	December	10 256	0.355	148	0.323
2022	January	<b>477 423</b>	<b>16,529</b>	<b>647</b>	<b>1,412</b>
	February	<b>318 867</b>	<b>11,040</b>	<b>1354</b>	<b>2,955</b>
	March	56 391	1,952	<b>482</b>	<b>1,052</b>
	April	28 615	0.990	122	0.266
	May	109 466	3,790	229	0.499
	June	90 606	3,137	360	0.785
	July	57 639	1,995	273	0.595
	August	33 202	1,149	19–2	0.419
	September	8156	0.294	87	0.189
	October	4187	0.144	35	0.076
	November	40 434	1,399	72	0.157
	December	92 805	3,213	252	0.550
<b>Total</b>		<b>2 888 258</b>	100.00	<b>45 815</b>	100.00

Source: Information extracted from the Coronavirus Panel on August 12, 2022<sup>15</sup>, available at: < <https://covid.saude.gov.br/> >.

As shown in Table 3, the first confirmed cases of COVID-19 in the state of Paraná were recorded in March 2020, accounting for 0.009% of the total cases over the analyzed period and six deaths in the same month, which corresponds to 0.01% of the total number of deaths for the entire analyzed period.

In 2020, the average number of confirmed COVID-19 cases and deaths in the state of Paraná was 37,039.58 and 776, respectively. The months with the highest number of confirmed COVID-19 cases were August (2.03%), November (2.97%) and December (4.35%). The months with the highest number of confirmed COVID-19 deaths were July (3.12%), August (3.42%) and December (5.07%).

In 2021, the average number of confirmed

COVID-19 cases and deaths was 93,802.67 and 2,699.83, respectively. Notable months for confirmed cases and deaths were March, May and June, accounting for 6.00%, 6.81% and 5.75% of the total number of cases and 14.22%, 10.75% and 11.88% of the total number of deaths, respectively.

In 2022, the average number of confirmed COVID-19 cases and deaths was 109 845.9 and 342.08 respectively. January stood out with 16.52% of the total number of cases, followed by February with 11.04% and May with 3.79%. On the other hand, the months with the highest number of deaths were January, February and March, with a relative frequency of 1.41%, 2.95% and 1.05% respectively. For both states, Table 4 shows the mortality, case fatality and incidence rates of COVID-19

**Table 4:** Monthly distribution of mortality, lethality and incidence rates of COVID-19 in the states of Santa Catarina and Paraná, Brazil, from January 2020 to December 2022

Year	Month	Santa Catarina			Paraná		
		Mortality (100.000 inhabitants)	Lethality (100%)	Incidence (100.000 inhabitants)	Mortality (100.000 inhabitants)	Lethality (100%)	Incidence (100.000 inhabitants)
2020	January	0	0	0	0	0	0
	February	0	0	0	0	0	0
	March	0.082	0.335	24.620	0.051	2.105	2.469
	April	0.688	<b>1.529</b>	44.975	0.953	<b>6.296</b>	15.140
	May	1.333	0.940	141.975	1.083	2.689	40.273
	June	3.165	0.672	470.742	5.416	<b>2.565</b>	211.092
	July	<b>12.399</b>	0.971	<b>1276.197</b>	<b>12.427</b>	<b>2.480</b>	501.078
	August	<b>14.601</b>	<b>1.977</b>	738.406	13.606	2.675	508.757
	September	7.101	<b>1.729</b>	410.531	10.772	2.509	429.240
	October	4.527	0.575	787.194	7.158	2.318	308.757
	November	9.785	0.479	<b>2040.174</b>	9.082	1.218	745.156
	December	<b>20.767</b>	1.427	<b>1454.558</b>	<b>20.149</b>	1.848	<b>1090.339</b>
	TOTAL	<b>74.45</b>	<b>1.00</b>	<b>7.390.44</b>	80.70	<b>2.09</b>	<b>3852.09</b>
2021	January	15.098	1.379	1142.321	17.148	1.669	1.027.252
	February	15.343	0.939	<b>1632.909</b>	17.614	1.894	929.539
	March	<b>50.640</b>	<b>2.863</b>	<b>1768.604</b>	<b>56.159</b>	<b>3.755</b>	<b>1.495.585</b>
	April	<b>33.733</b>	<b>3.277</b>	1029.165	38.916	4.368	890.889
	May	<b>23.504</b>	2.048	<b>1147.666</b>	42.466	2.502	1.697.199
	June	20.688	1.969	1050.547	46.904	3.276	1.431.385
	July	14.731	2.121	694.375	22.620	3.614	625.765
	August	9.494	1.796	528.470	13.718	2.257	607.659
	September	7.181	1.898	378.207	11.702	2.246	520.882
	October	5.168	1.817	284.339	7.195	2.721	264.383
	November	4.053	2.226	182.023	3.464	2.859	121.161
	December	2.475	1.163	212.737	1.275	1.443	88.380
	TOTAL	<b>202.11</b>	<b>2.02</b>	<b>10.051.36</b>	<b>279.18</b>	<b>2.87</b>	<b>9.700.08</b>
2022	January	<b>6.630</b>	0.146	<b>4539.460</b>	<b>5.545</b>	0.135	<b>4092.328</b>
	February	<b>10.207</b>	0.691	<b>1475.215</b>	<b>11.606</b>	0.424	<b>2733.233</b>
	March	<b>3.268</b>	1.487	219.696	<b>4.131</b>	<b>0.854</b>	483.366
	April	0.874	0.495	176.418	1.045	0.426	245.279

**Continuatioin - Table 4:** Monthly distribution of mortality, lethality and incidence rates of COVID-19 in the states of Santa Catarina and Paraná, Brazil, from January 2020 to December 2022

Year	Month	Santa Catarina			Paraná		
		Mortality (100,000 inhabitants)	Lethality (100%)	Incidence (100,000 inhabitants)	Mortality (100,000 inhabitants)	Lethality (100%)	Incidence (100,000 inhabitants)
	May	1.048	0.187	559.165	1.962	0.209	938.310
	June	2.272	0.365	<b>622.359</b>	3.085	0.397	776.647
	July	2.797	0.562	497.315	2.34	0.473	494.064
	August	1.492	<b>0.869</b>	171.724	1.645	0.578	284.597
	September	0.551	<b>1.17</b>	47.096	0.745	1.021	72.996
	October	0.161	0.362	44.501	0.300	0.835	35.889
	November	0.753	0.153	489.972	0.617	0.178	346.588
	December	1.775	0.312	567.906	2.16	0.271	795.496
	TOTAL	31.832	0.338	9.410.832	35.186	0.311	11 298.799
Total	308.40	1.14	26.852.64	395.07	1.58	24.850.98	

When comparing the case fatality rates between the states of Santa Catarina and Paraná, it was noted that the overall rate remained higher in the state of Paraná throughout the period analysed, with notable peaks in April 2020 (1.52%), April 2021 (3.27%) and July 2022 (0.56%).

In terms of incidence, Santa Catarina stands out compared to the other states, with higher rates. In 2021, the highest incidence rate for COVID-19 was observed in Santa Catarina, with a total of 10,051.36 per 100,000 inhabitants. This compares to a rate of 9,700.08 per 100,000 inhabitants in the state of Paraná.

Similar to the case fatality rate, the mortality in Paraná was higher in all periods, with the highest observed in the year 2021 with a rate of 279.18 per 100,000 inhabitants.

Trends of mortality, case fatality, and incidence rates of COVID-19 in the states of Santa Catarina and Paraná can be visualised in Table 5. For analyses considered statistically significant ( $p < 0.005$ ), The DPC reveals the percentage of daily variation, showing the increase or decrease for the variables.

**Table 5:** Prais-Winsten regression estimates and daily percentage variation (DPV) of mortality, lethality and incidence rates of COVID-19 in the states of Santa Catarina and Paraná, Brazil, from January 2020 to December 2022

RATE/YEAR	LINEAR REGRESSION				
	$\beta$	P	VPD	(IC95%)	Trend
SANTA CATARINA					
MORTALITY					
2020 to 2022	-0.00057	0.022	-0.13	-0.24; -0.02	Descending
2020	- 0.0052064	<0.001	1.21	0.90; 1.51	Growing
2021	-0.0029476	<0.001	-0.68	-0.86; -0.49	Descending
2022	-0.0022546	<0.001	-0.52	-0.73; -0.31	Descending
LETHALITY					
2020 to 2022	-0.0004837	<0.001	-0.11	-0.16; -0.06	Descending
2020	-0.0010693	0.031	-0.25	-0.47; -0.02	Descending
2021	-0.0000551	0.847	-0.01	-0.14; 0.12	Stationary
2022	0.0009924	0.106	0.23	-0.05; 0.51	Stationary
INCIDENCE					
2020 to 2022	0.0002509	0.625	0.06	-0.17; 0.29	Stationary
2020	0.0066926	<0.001	1.55	1.12; 1.98	Growing
2021	-0.0028518	<0.001	-0.65	-0.78; -0.53	Descending
2022	-0.0027203	0.129	-0.62	-1.43; 0.18	Stationary
PARANÁ					
MORTALITY					



**Continuation - Table 5:** Prais-Winsten regression estimates and daily percentage variation (DPV) of mortality, lethality and incidence rates of COVID-19 in the states of Santa Catarina and Paraná, Brazil, from January 2020 to December 2022

RATE/YEAR	LINEAR REGRESSION				
	$\beta$	P	VPD	(IC95%)	Trend
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	Growing
2021	-0.0035531	<0.001	-0.81	-1.13; -0.50	Descending
2022	-0.0026543	<0.001	-0.61	-0.61; -0.84	Descending
<b>LETHALITY</b>					
2020 to 2022	-0.0010223	<0.001	-0.24	-0.28; -0.19	Descending
2020	-0.0019057	<0.001	-0.44	-0.56; -0.31	Descending
2021	-0.0001992	0.351	-0.05	-0.14; 0.05	Stationary
2022	0.0008202	0.069	0.19	-0.01; 0.39	Stationary
<b>INCIDENCE</b>					
2020 to 2022	0.0016438	0.001	0.38	0.16; 0.60	Growing
2020	0.0118071	<0.001	2.76	1.94; 3.58	Growing
2021	-0.0033085	<0.001	-0.76	-0.94; -0.58	Descending
2022	-0.0030327	<0.001	-0.70	-1.08; -0.31	Descending

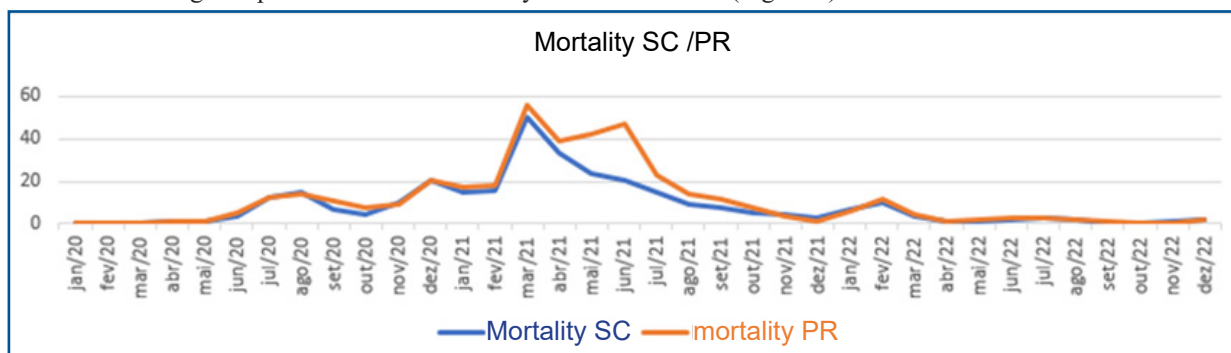
$\beta$  – regression coefficient; P – p-value; VPD – Daily percentage variation; 95% CI – 95% confidence interval.

\* Statistical difference detected by the Prais-Winsten regression test,  $p < 0.05$ .

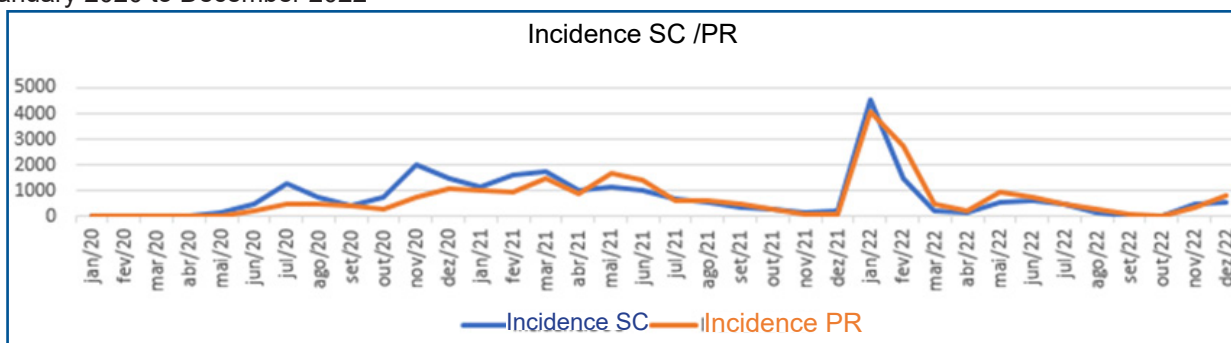
For the State of Santa Catarina, when the rates were analyzed over the whole period, the trends for mortality, case fatality, and incidence are decreasing, decreasing, and stationary, respectively. However, for the State of Paraná, for the same rates and period, the behaviour is stationary, decreasing and increasing, respectively.

If we analyze the incidence curve (Figure 1), we can see that the highest peak occurred in January 2022

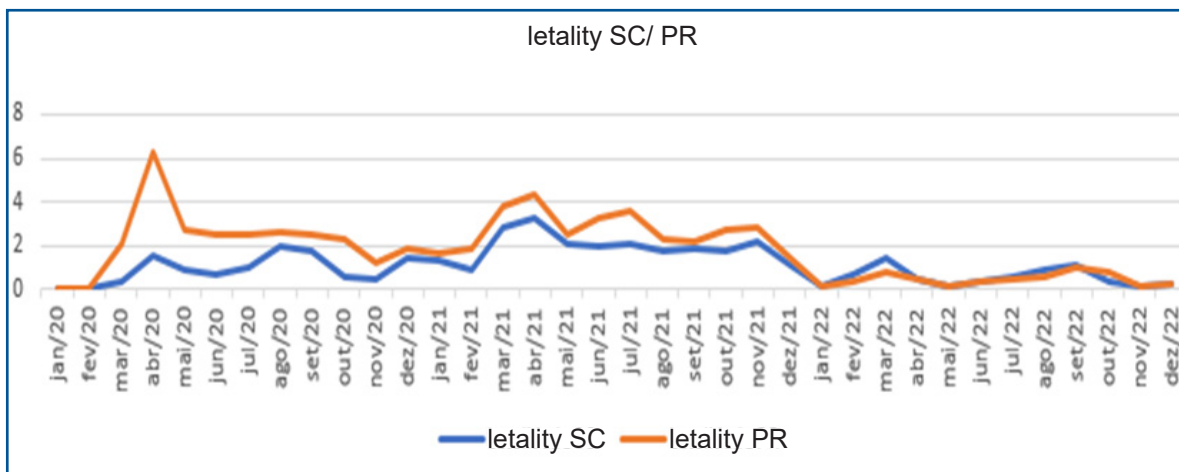
when the state of Santa Catarina had higher incidence values, with a more pronounced decline compared to the state of Paraná. The incidence peaks from January 2020 were higher in Santa Catarina until March 2021, when a higher incidence was observed in the state of Paraná. From there, the curves remained similar until May 2022 when a peak incidence of COVID-19 was observed in the state of Paraná (Figure 1).”



**Figure 1 -** Trend analysis of COVID-19 mortality rates in the states of Santa Catarina and Paraná, Brazil, from January 2020 to December 2022



**Figure 2:** Trend analysis of COVID-19 incidence rates in the states of Santa Catarina and Paraná, Brazil, from January 2020 to December 2022



**Figure 3:** Trend analysis of COVID-19 letality rates in the states of Santa Catarina and Paraná, Brazil, from January 2020 to December 2022

When observing the trend analysis graph of mortality (Figure 2), it was found that the peak of both curves started in February 2021, reaching its highest point in March.

The state of Paraná maintained a higher mortality rate, with another peak in June 2021, while the state of Santa Catarina continued to decline. The last peak observed until December 2022 was in February 2022 for both states (Figure 2).

In the graph (Figure 3), it is noticeable that case fatality was higher in the year 2020 in the states of Paraná and Santa Catarina in the initial phase of the disease. The peak for both states can be observed in April 2020, with Paraná showing higher percentiles compared to Santa Catarina. There was a significant increase in the number of deaths in both states in April 2021, although Paraná remained higher. From January 2022, there was a reversal in the curves, and it is possible to observe that until April 2022, the case fatality rates are higher in the State of Santa Catarina (Figure 3).

## DISCUSSION

The factors and outcomes of the COVID-19 pandemic are influenced by socio-demographic inequalities, geographical location, and political and religious ideology. Therefore, it is necessary to study and compare states with different socioeconomic characteristics in Brazil, as these inequalities may cause differences in mortality, incidence, and case fatality rates.

In the United States, a study analysed how social conditions in the country's counties were related to differences in COVID-19 mortality rates. The results showed that black race, the percentage of Hispanics and income inequality were associated with higher mortality rates. Thus, regional social conditions are strong predictors of how the pandemic was experienced and where there was a greater loss of life<sup>20</sup>.

Based on the data presented, the state of Paraná shows significant differences in the distribution of pandemic compared to the state of Santa Catarina. These differences are explained by several factors, including population density, age distribution, health status, and the timing of disease onset in communities and regions<sup>21</sup>.

Throughout the pandemic, the southern region had the lowest incidence and mortality rates.

One socioeconomic inequality indicator is the Human Development Index (HDI), which encompasses factors such as development issues, infrastructure, human rights, public policies, economy, and social aspects<sup>22</sup>.

The HDI for the Brazilian states included in this study is 0.749 for Paraná and 0.774 for Santa Catarina. In the analysis of COVID-19 mortality, it was observed that Paraná maintained a higher mortality rate, which is consistent with the findings of Rambotti, Wolski, and Anderson<sup>20</sup>, who found a higher mortality rate in regions with greater socioeconomic inequality.

In addition, the case fatality rate was higher in Paraná than in Santa Catarina in all periods, with the highest observed in 2021 with a rate of 279.188 per 100,000 inhabitants, 1.38 times higher than in Santa Catarina.

The results of an ecological analytical study that analyzed COVID-19 incidence in association with social determinants of health in the Northeast region of Brazil<sup>23</sup> also supported our findings, as well as those of Rambotti, Wolski, and Anderson<sup>20</sup>. Socioeconomic factors and social indicators such as the Gini Index, literacy rate, percentage of people living below the poverty level, and people living in poverty-vulnerable households are factors of higher COVID-19 incidence in the Brazilian Northeast<sup>23</sup>.

The Gini Index measures the degree of income concentration and, consequently, social inequality. The index can range from 0 to 1, with values closer to zero indicating lower concentration. In 2020, Paraná had a Gini Index for the distribution of Gross Domestic Product (GDP) of 0.755, the lowest since 2002. Social distancing measures due to the pandemic favored this decline, as the service sector was affected<sup>24</sup>.

In the same year, Santa Catarina's Gini Index was 0.550, indicating lower social inequality compared to Paraná<sup>25</sup>. According to the results of Dos Santos Alves<sup>23</sup>, which indicate a higher COVID-19 incidence in regions with worse socioeconomic factors and social indicators, Santa Catarina stands out compared to Paraná. Santa Catarina had the highest incidence rate, with 10,051.36 cases per 100,000 inhabitants, compared with 9,700.084 cases per 100,000 inhabitants in Paraná.

In addition, Paraná's per capita income is lower than that of Santa Catarina, which had lower case fatality and mortality rates but higher incidence rates, possibly due to the state's diagnostic capacity.

It is also worth noting that isolation in the Southern region may have been more effective due to the socioeconomic factors of residents<sup>26</sup>, considering that the number of cases was higher in regions with lower per capita GDP, such as the North and Northeast regions<sup>27</sup>.

The results of an epidemiological study using data from the John Hopkins Institute and the Ministry of Health during the first 65 days of the pandemic in the Southern region of Brazil showed that, although the state of Santa Catarina having a higher number of cases, Paraná accounted for the highest number of deaths and the highest case fatality rate in the Southern region<sup>10</sup>. These results are consistent with our study in the months of March and April in the year of 2020, where the number of deaths was higher in the State of Paraná, even though the number of infected individuals was higher in Santa Catarina.

COVID-19 is a significant global health threat, with millions of confirmed cases and deaths worldwide, impacting several healthcare systems, including those in Brazil.

Brazil presents a complex epidemiological scenario due to regional differences and its large continental size<sup>28</sup>. A high number of cases and deaths were observed in the states of Santa Catarina and Paraná, two states in the southern region of Brazil. This study was undertaken due to the need for a detailed assessment and comparison of the epidemiological context between the States.

The epidemiology of COVID-19 deserves special attention given the high clinical, social and economic burden and the high mortality, incidence and case fatality rates observed. On a broader scale, it is known that approximately one third of the world's population may have been exposed to SARS-CoV-2 infection, a number that is likely to increase as the virus continues to circulate<sup>29</sup>.

Despite the decline in the severity of acute COVID-19 infection and the gradual decrease in the numbers of deaths following the implementation of restriction measures, vaccine distribution, virus attenuation, the development of natural immunity, and better therapeutic management, it is important to recognize the importance of epidemiological studies on the disease, even after declaring the end of the pandemic.

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In response to the COVID-19 pandemic, several containment and mitigation interventions were implemented to avoid overwhelming health systems and protect vulnerable populations<sup>30</sup>. Measures such as social distancing, hand hygiene, masks, quarantine and isolation have proven effective in reducing SARS-CoV-2 transmission, but vaccination has also played a critical role in minimizing the risk of severe COVID-19<sup>7,28,31</sup>.

Over these three years of the COVID-19 pandemic, there has been a possible demonstration of the crucial role of vaccination in reducing the burden of COVID-19 disease in the populations of Paraná and Santa Catarina. There is a protective effect of vaccination against complications and deaths related to COVID-19<sup>32</sup>, especially among those who received complete primary vaccination and booster doses. The implementation of a mass vaccination campaign could significantly reduce pressure on the healthcare system and society, positively impacting the pandemic trajectory in these two southern Brazilian states.

The limitations of this research relate to changes for adjustments in the databases used, as small variations may occur. However, these would not affect the interpretation of the results or the conclusions of the study.

Furthermore, the results presented are partial data, as the pandemic continues to be studied. The number of cases found may be higher, given the limitations of mass testing for COVID-19 detection.

## CONCLUSION

The abrupt increase in the number of infections and deaths harmed the healthcare structure of the states of Paraná and Santa Catarina, demonstrating the need for public policies in managing the pandemic.

When comparing the epidemiological outcomes of incidence, case fatality, and mortality due to COVID-19 between the states of Santa Catarina and Paraná in the southern region of Brazil, it is observed that the state of Paraná had higher rates of case fatality and mortality, while the state of Santa Catarina had a higher incidence rate throughout the analyzed period.

It was noted that mass immunization had a positive impact against the evolution of the pandemic, resulting in a stationary trend in incidence for both states. Therefore, public health policymakers must remain vigilant in monitoring COVID-19 data and adapt interventions according to the active and informed engagement of all relevant stakeholders, including citizens.

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## Resumo

**Introdução:** no Brasil, o primeiro caso por COVID-19 foi confirmado em 26 fevereiro de 2020. Até o dia 17 março de 2023, o Ministério da Saúde contabilizou 699.634 mortes por COVID-19, com uma taxa de letalidade de 1,9%. O impacto da pandemia da COVID-19 no Brasil nas esferas socioeconômicas e de sistema de saúde é reflexo das grandes diferenças regionais.

**Objetivo:** analisar a mortalidade, incidência e letalidade por COVID-19 nos estados do Paraná e Santa Catarina, região sul brasileira.

**Método:** trata-se de estudo ecológico de séries temporais utilizando dados secundários oficiais brasileiros para os casos e mortes por COVID-19. Os dados foram extraídos do painel da Secretaria Estadual de Saúde dos estados de Santa Catarina e Paraná. Para a análise da tendência, desenvolveu-se séries temporais a partir do modelo de regressão de Prais-Winsten. As análises estatísticas foram realizadas com o uso do software STATA 14.0 (College Station, TX, EUA, 2013).

**Resultados:** na análise dos resultados no período total analisado, as tendências para mortalidade, letalidade e incidência no estado de Santa Catarina são decrescente, decrescente e estacionária, respectivamente. Já no estado do Paraná, os resultados no período total apresentaram tendência estacionária, decrescente e crescente para mortalidade, letalidade e incidência, respectivamente.

**Conclusão:** a COVID-19 provocou um efeito devastador sobre os estados de Santa Catarina e Paraná. Ambos os estados sofreram com o andamento da pandemia COVID-19, sendo que no estado do Paraná observou-se maiores taxas de letalidade e mortalidade, enquanto Santa Catarina obteve maior taxa de incidência ao longo dos três anos de vigência da pandemia da COVID-19.

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

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