Archives of Current Research International

Volume 25, Issue 7, Page 638-647, 2025; Article no.ACRI.139635
ISSN: 2454-7077

Covid-19 Epidemiology in the Southern Brazilian States from 2020 to 2024

Eduarda Caroline Ceriolli Martinello [a++*], Almir Walker [a#], Junir Antônio Lutinski [b†], Maria Assunta Busato [b†], Sinval Adalberto Rodrigues Junior [b†] and Thiago André Carniel [b†]

[a] Stricto Sensu Graduate Program in Health Sciences, Unochapecó, Brazil.
[b] Stricto Sensu Postgraduate Program in Health Sciences, Unochapecó, Brazil.

Authors' contributions

This work was carried out in collaboration among all authors. Authors' ECCM, AW, JAL, MAB, SARJ and TAC designed the study, collected the data, performed the statistical analysis and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/acri/2025/v25i71365

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/139635

Original Research Article

Received: 05/05/2025
Accepted: 10/07/2025
Published: 17/07/2025

ABSTRACT

Aims: analyze the epidemiology of Covid-19 in southern Brazil from 2020 to 2024
Study Design: this is an epidemiological, descriptive and cross-sectional study.
Place and Duration of Study: Brazil. held from April to June 2024.
Methodology: data from the IT Department of the Unified Health System were utilized. The Kruskal–Wallis test was employed to compare and analyze the incidence, mortality, and lethality of COVID-19 across the states and municipalities of southern Brazil. The associations between

[++] PhD Student;
[#] Master's Student;
[†] Professor;
**Corresponding author: Email: duda_eduardaceriolli@outlook.com;*

Cite as: *Martinello, Eduarda Caroline Ceriolli, Almir Walker, Junir Antônio Lutinski, Maria Assunta Busato, Sinval Adalberto Rodrigues Junior, and Thiago André Carniel. 2025. "Covid-19 Epidemiology in the Southern Brazilian States from 2020 to 2024". Archives of Current Research International 25 (7):638-47. https://doi.org/10.9734/acri/2025/v25i71365.*

variables were assessed using the Chi-square test in the Past software. Spatial distribution maps of incidence and mortality in the region were generated using MATLAB.
Results: Paraná recorded the highest mortality rate (410,1 per 100.000 inhabitants) and lethality rate (1,6%) among the three states. However, the Paraná region had the lowest incidence of cases (26.367,3 per 100.000 inhabitants). Rio Grande do Sul had an incidence of 28.886,6 per 100.000 inhabitants, a mortality rate of 374,4 per 100.000 inhabitants, and a lethality rate of 1.4%. Finally, Santa Catarina had an incidence of 27.353,8 per 100.000 inhabitants and the lowest mortality (303,5 per 100.000) and lethality (1,1%) rates compared to the other regions. Cases and deaths were more concentrated in regions bordering Argentina and Paraguay, as well as along the borders with the states of Mato Grosso do Sul and São Paulo, in addition to the coastal areas. In 2022, the highest incidence was recorded across all states in the region, while the highest lethality and mortality rates occurred in 2021.
Conclusion: the mortality and lethality rates of COVID-19 were not homogeneous among the states in the southern region. The distribution of mortality and lethality in the region for each year evaluated may be attributed to the stage of population immunization and the predominant variant. These data are important for guiding public health policies in the management of future pandemics.

Keywords: Coronavirus; lethality; mortality; pandemic; epidemiology.

1. INTRODUCTION

The novel coronavirus is a strain of the coronavirus family, first identified in humans in December 2019 in Wuhan, China (OPAS, 2023). SARS-CoV-2 causes COVID-19, an acute, potentially severe, and highly transmissible infectious disease. On January 30, 2020, the World Health Organization declared COVID-19 a public health emergency of international concern, and on March 11, 2020, it declared it a pandemic due to its widespread global distribution. In Brazil, the first case of Covid-19 was reported on February 26, 2020, and as of March 17, 2023, the country had record 37.145.514 cases and 699.634 deaths (Brasil, 2024).

The Brazilian epidemiological scenario regarding Covid-19 is complex due to the country's vast territorial extent and the climatic, environmental, cultural, and socioeconomic heterogeneity characteristic of each region (Brazilian Institute of Geography and Statistics, 2023). Therefore, it is evident that the distribution of cases and deaths across the various Brazilian regions and states did not occur uniformly, varying according to the factors described above (Brito, et al., 2023).

The southern region of Brazil comprises the states of Santa Catarina, Paraná, and Rio Grande do Sul and has the highest Human Development Indexes in the country. According to the data, Santa Catarina, Rio Grande do Sul, and Paraná have Human Development Indexes of 0,792, 0.771, and 0,769, respectively (Pan American Health Organization, 2023). Among the studies conducted in the southern region that aimed to compare the prevalence of Covid-19 cases and deaths among its states, two were based solely on data from 2020 (Lopes, et al., 2020; Klokner, et al., 2021). The international public health emergency due to Covid-19 was only declared over in May 2023, and the pandemic situation has not yet been eradicated (Klokner, et al., 2021 and Brito, et al., 2023).

Thus, despite the lower severity of cases and the significant reduction in the number of deaths, epidemiological studies on COVID-19 are essential to provide public health indicators that support disease monitoring, tracking and planning for the management of current and future pandemics. In this context, this study analyzed Covid-19 epidemiological data from the states of southern Brazil.

2. METHODOLOGY

2.1 Study Characteristics

Epidemiological, cross-sectional, descriptive study.

2.2 Data Collection

Data were collected from the interactive panel of the Department of Informatics of Sistema Único de Saúde (SUS), covering epidemiological weeks 13 of 2020 through 17 of 2024. The variables collected included the number of cases and deaths for the three states in the southern region of Brazil, as well as for each of the 1.191 municipalities within region.

The incidence, mortality, and lethality rates were stratified for each year from 2020 to 2024, for each of the three states and for each of the 1.191 municipalities in the southern region. Population data from the Brazilian Institute of Geography and Statistics were used, considering each year from 2020 to 2024 and each state in the southern region. The data were organized and analyzed using Microsoft Excel.

2.3 Data Analysis

Data on incidence, mortality, and case fatality rates were analyzed from an epidemiological perspective. The Kruskal–Wallis test was used to compare and correlate incidence, mortality, and lethality rates across the three states in the southern region. A significance level of $p < 0,005$ were considered. The association between variables was assessed using the Chi-square. The Past software was used.

Maps illustrating the spatial distribution of incidence and mortality in the region were created using the Matlab program. The 1.191 municipalities were grouped into four categories based on incidence: 0-5.000, 5.001-20.000, 20.001- 40.000, and more than 40.000 cases per 100.000 inhabitants. For mortality, municipalities were stratified into the following categories: 0-100, 101-200, 201-500, and over 500 COVID-19 deaths per 100.000 inhabitants.

3. RESULTS

Rio Grande do Sul (RS) recorded the highest incidence of Covid-19 during the evaluated period, with 28.886,6/100.000 inhabitants, followed by Santa Catarina (SC), with 27,353.8 cases per 100.000 inhabitants. Paraná (PR) had the lowest incidence at 26.367,3 cases per 100.000 inhabitants but exhibited the highest mortality rate at 410,1 deaths per 100.000 inhabitants and the highest case fatality rate at 1,6%. Rio Grande do Sul had a mortality rate of 374,4 deaths per 100.000 inhabitants in a case fatality rate of 1,4%. Among the three stats, Santa Catarina had the lowest mortality rate at 303,5 deaths per 100.000 inhabitants and the lowest case fatality rate at 1,1%.

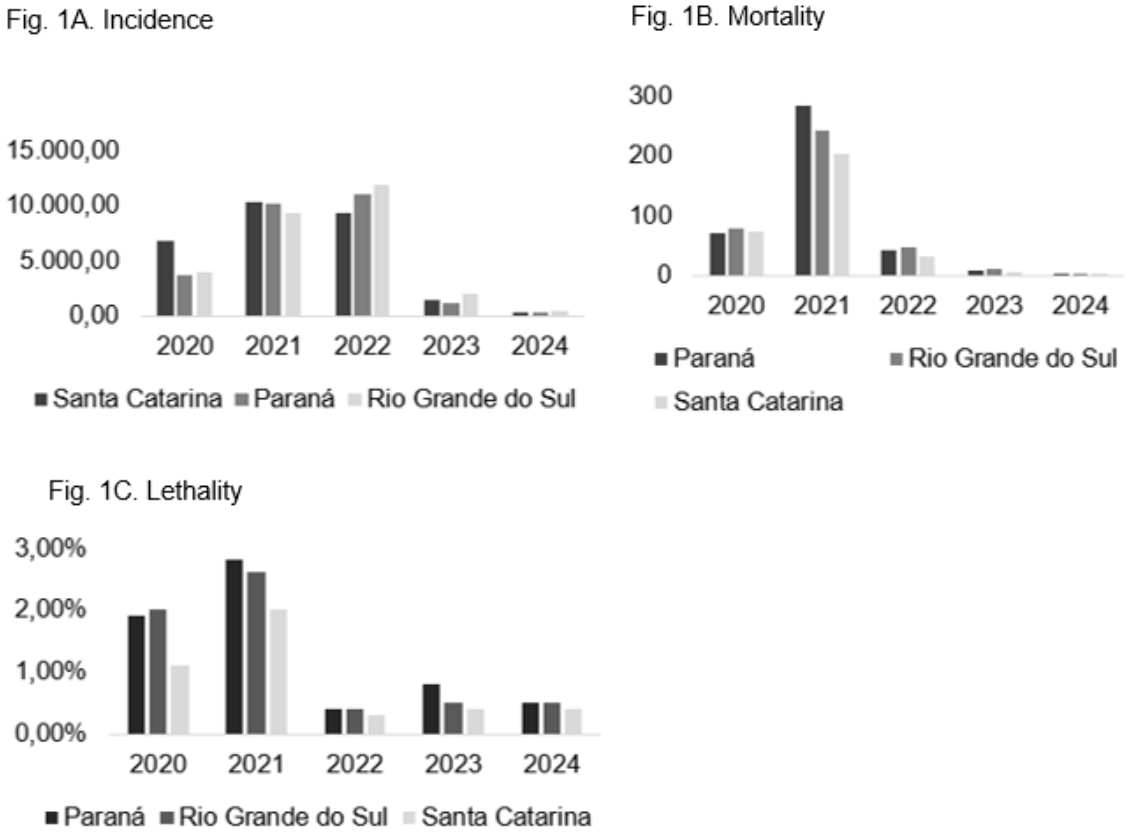

Fig. 1. Incidence, mortality, and lethality rates of COVID-19 in the states of southern Brazil from 2020 to 2024

Regarding the distribution of cases over the analyzed period, it was found that in 2020, Santa Catarina had a higher incidence than the other states, with 6.792,2 case per 100.000 inhabitants, while Rio Grande do Sul registered 3.936,6 and Paraná 3.617,0. In 2021, Santa Catarina also had the higher disease incidence (10.233,0 cases). In 2022, Rio Grande do Sul led the region in the number of cases, with an incidence of 11.825,8, followed by Paraná with 10.906,1. In 2023, incidence rates declined significantly (Fig. 1A).

The highest mortality and lethality rates were recorded between 2020 and 2021, with 2021 standing out as the most critical year of the pandemic. In 2022, despite the higher incidence, there was a decline in both mortality and lethality. From 2023 onwards, mortality rates decreased in the three states, while lethality showed a slight increase compared to 2022. By epidemiological week 17 of 2024, lethality in the three southern states was already comparable to that recorded in the previous year (Fig. 1B and Fig. 1C).

Despite the higher incidence in 2020 and 2021, Santa Catarina had lower mortality and lethality rates compared to the other evaluated states. In 2020, the mortality rate was 72,5 and the lethality rate was 1,1%. Rio Grande do Sul had a mortality rate of 77,7 and a lethality rate of 2,0%, while Paraná had a mortality rate of 69,2 and a lethality rate of 1,9%. In 2021, Paraná had a mortality rate of 283,4 and a lethality rate of 2,8%, Rio Grande do Sul 240,5 and 2,6% and Santa Catarina 203,5 and 2,0%, respectively (Fig. 1B and Fig 1C).

No significant differences were observed in the incidence of Covid-19 among the three states of the Southern region (p-value = 0.07) (Fig. 2). The average incidences were 27,312.4 (minimum = 2,060.4; maximum = 57,390.2; 95% confidence interval: (26,514-28,110), 26,051.4 (minimum = 2,159.5; maximum = 56,093.7; 95% CI: (25,222-26,881) and 26,465.0 (minimum = 1,862.1; maximum = 51,859.7; 95% CI: (25,522-27,408) for PR, RS, and SC, respectively.

The mortality rate was significantly higher in Paraná (p-value < 0,001), as was the case fatality rate (p-value < 0,001) (Fig. 3 and Fig. 4). The average mortality were 357.0 (minimum = 66.1; maximum = 851.1; 95% confidence interval: (344.3-369.7), 302.2 (minimum = 0; maximum = 868.1; 95% CI: (290.8-313,6) and 296.5 (minimum = 0; maximum = 723.4; 95% CI: (283.5-309.4)) for PR, RS, and SC, respectively.

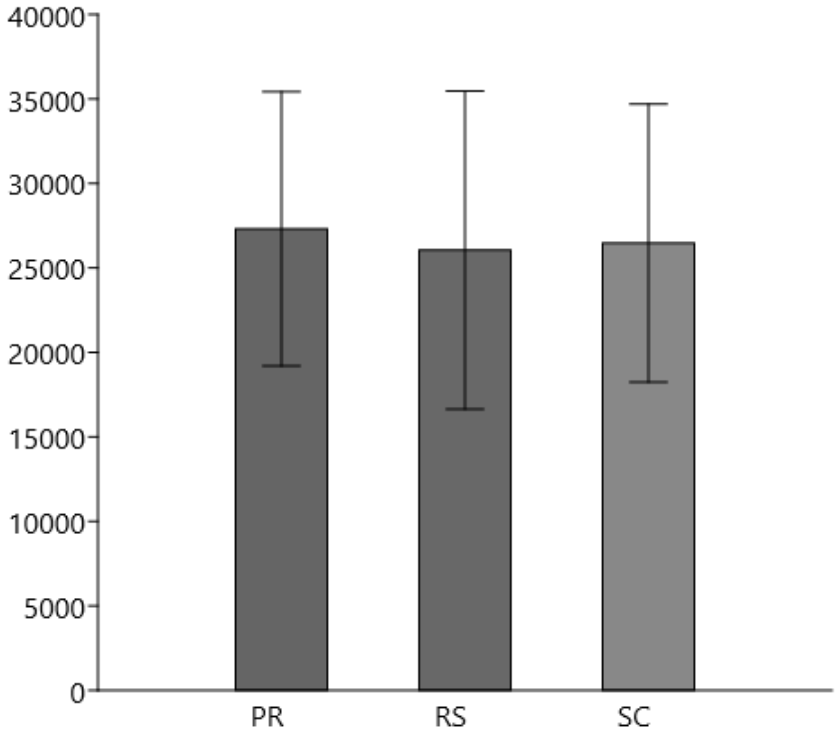

Fig. 2. Comparison of the incidence of COVID-19 in the states of the Southern region of Brazil from 2020 to 2024

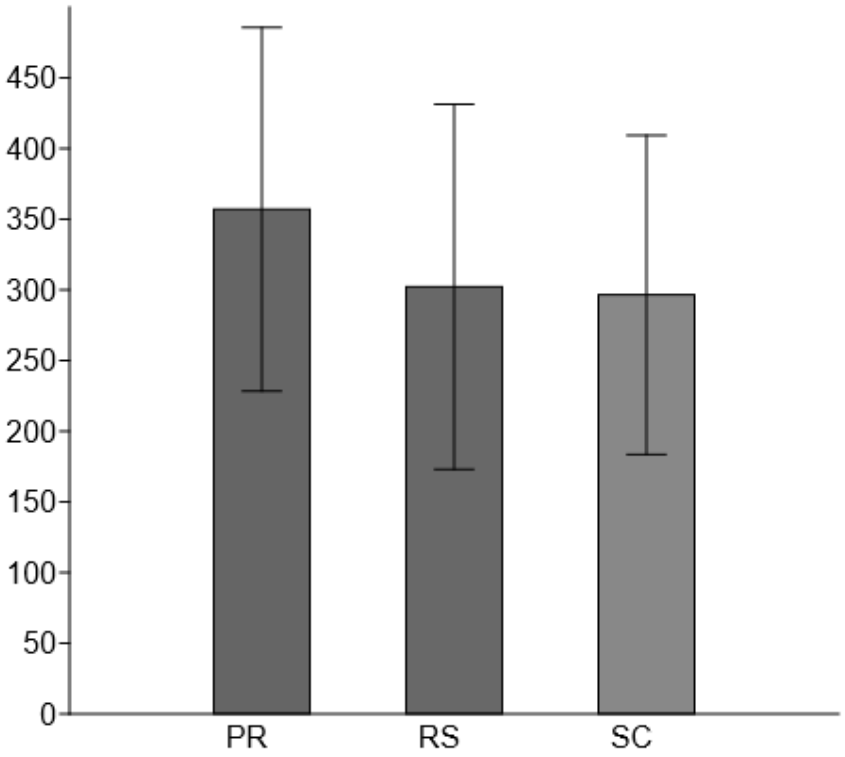

Fig. 3. Comparison of Covid-19 mortality in the states of southern Brazil from 2020 to 2024

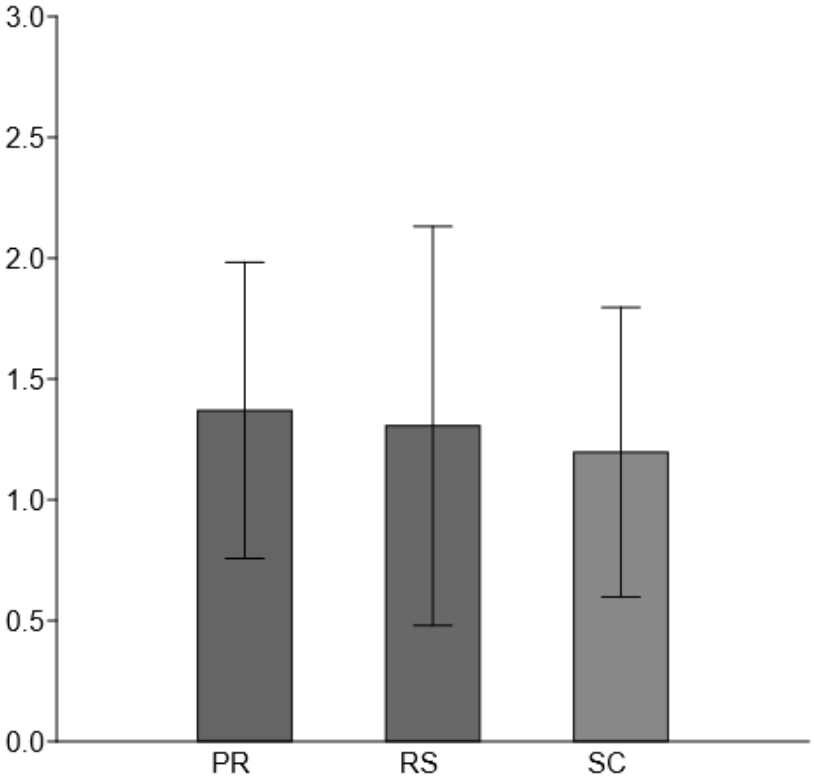

Fig. 4. Comparison of Covid-19 mortality rates in the states of southern Brazil from 2020 to 2024

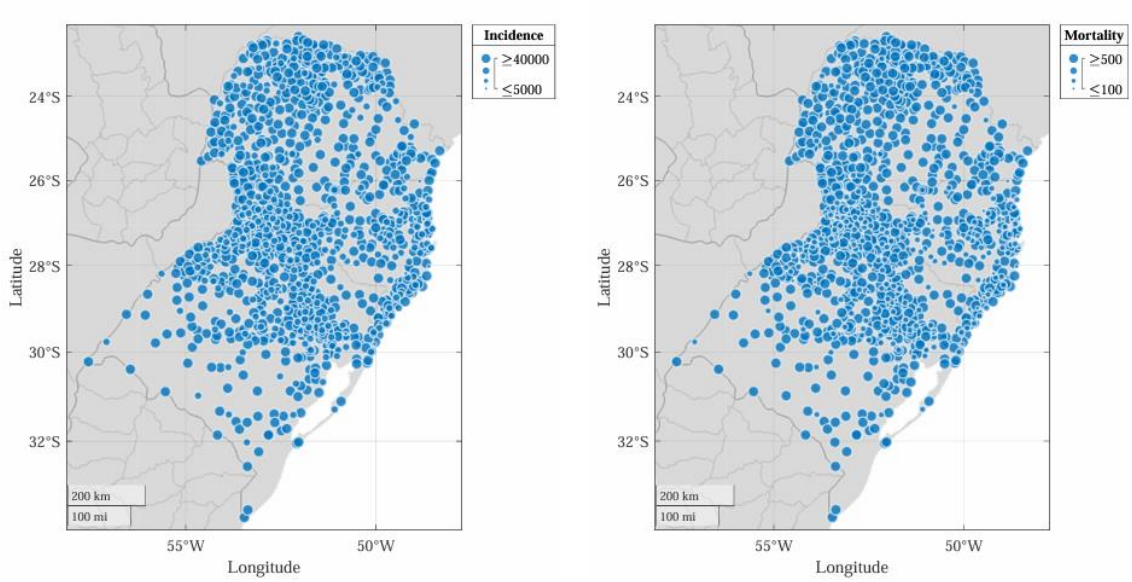

Fig. 5. Distribution of Covid-19 incidence and mortality among the states of southern Brazil from 2020 to 2024

The average lethality were 1.36 (minimum = 0.23; maximum = 6.92; 95% confidence interval: (1.31-1.43)), 1.31 (minimum = 0; maximum = 7.76; 95% CI: (1.23-1.39)) and 1.20 (minimum = 0; maximum = 5.23; 95% CI: (1.13-1.26)) for PR, RS, and SC, respectively.

The incidence and mortality rates for COVID-19 exhibited similar distribution patterns. It was observed that both cases and deaths were concentrated in municipalities situated in regions bordering Argentina and Paraguay, as well as in areas bordering the states of Mato Grosso do Sul and São Paulo, along with coastal regions (Fig. 5).

4 DISCUSSIONS

It was found that, although the southern states varied in the strictness of measures to contain the spread of the pandemic, they generally followed the national trend. The only period during pandemic that involved a significant decrease in human mobility due to restrictions and lockdown measures was between April and May 2020 (Nagamine, et al., 2020; Razafindrakoto, et al., 2024). Additionally, it´s also important to consider the underreporting of cases resulting from reduced testing in the states, especially in the first year of the pandemic. This underreporting should therefore be acknowledged as a limitation.

The higher mortality and lethality rates observed in Paraná, along with the differences between them, indicate that the pandemic impacted the state more severely than others. During the pandemic, Paraná had the lowest rate of intensive care unit (ICU) beds dedicated exclusively to COVID-19 (8,99 per 100.000 inhabitants), whereas Santa Catarina had the highest (12,82 per 100.000 inhabitants), followed by Rio Grande do Sul (9,59 per 100.000 inhabitants) (Covre, et al., 2022). The lower proportion of ICU beds may have contributed to some severe cases not receiving adequate treatment, potentially leading to death (Razini, et al., 2021 and Oliveira, et al., 2022). Factors such as the speed of viral spread, population size, and population density may also explain the severity of the impact on the state. Paraná's population exceeds that of other states in the region and its population density of 57,42 inhabitants per square kilometer is higher than both the national average of 23,86 inhabitants/km^2 and in the regional average of 51,0 inhabitants/km^2 (Bezerra, et al., 2020; IBGE, 2023).

Data on the profile of cases that resulted in death from COVID-19 in the region could contribute to understanding the variations in COVID-19 lethality and mortality among the southern states. It´s well established that the disease was more lethal among individuals over 60 years of age, those with comorbidities, and males (Klokner, et al., 2021; Renck, et al., 2024 and Oliveira, et al., 2022). The population of Paraná comprises approximately 16% elderly individuals, whereas in Rio Grande do Sul, this percentage is around

18% (IBGE, 2023b). Additionally, literature reports mortality rates between 65% and 70% among populations over 60 years of age in the southern states, particularly in Rio Grande do Sul (Paraná, 2024; Rio Grande do Sul, 2024 and Santa Catarina, 2024). However, the absence of detailed data limited the scope of this analysis. Furthermore, it is not possible to attribute Paraná's higher mortality and lethality rates solely to a single factor. These outcomes are likely influenced by a combination of factors, including more relaxed prevention measures, higher population density, reduced availability of health services through the Unified Health System (SUS), and a higher proportion of elderly resident in the region.

When comparing Paraná with other regions of the country, it´s evident that mortality in Paraná was similar to that in the Midwest (411,3 per 100.000 inhabitants) and higher than in the Southeast (388,2 per 100.000 inhabitants), which recorded the highest mortality rates for the period evaluated. Conversely, the lethality rates in the Southern states were lower than those observed in Brazil most affected regions, such as the Southeast (2,2%), Northeast (1,8%), and North (1,7%) (Brasil, 2024). It´s possible that the pandemic manifested less severely in the South due to the greater availability and quality of healthcare services to meet demands (Razini, et al., 2021). Nonetheless, it´s important to not that Paraná's mortality rates approached those of the North and Northeast regions, underscoring the severity with which the pandemic particularly impacted the state.

Furthermore, Paraná is located in a geographical area that borders Argentina and Paraguay. Maps depicting the distribution of Covid-19 cases and deaths in the region show a higher concentration of incidence and mortality in the border areas. These border regions are characterized by commuter migration, with increased movement of people for work, tourism, consumption, and use of public services and education. Although these borders were closed for a certain period during the pandemic, economic necessity prompted many individuals to resume their work activities early, as the state's mitigation measures to reduce the economic impact were insufficient (Silva-Sobrinho et al., 2021). Additionally, it should be noted that the border region is heavily influenced by informal economy activities, which involve workers traveling to sell products and services and are often characterized by a lack of social security coverage (Oliveira Neto, et al., 2020).

Borders are political territorial boundaries; therefore, neighboring territories may share public health challenges that require coordinated management among municipalities for the development of health surveillance actions. However, this shared management is often difficult, particularly due to differences between the health systems of each country (Santos-Melo, et al., 2023). During the pandemic, it was observed that joint management of Covid-19 health surveillance between municipalities along international borders did not occur, which contributed to increased contamination and viral spread in these areas (Nagamine, et al., 2020).

Coastal regions also exhibited a significant concentration of Covid-19 cases, which is believed to be due to the density, concentration, multiplicity, multidirectionality of flows, as well as the large number of people moving within these areas. Additionally, it was observed that the locations with the highest concentrations of incidence and mortality on the maps include inland cities, corroborating data from the literature indicating that inland cities experienced higher numbers of cases and deaths compared to capital cities. This may be related to premature decisions by municipalities to relax social distancing measures, without a basis in state and federal guidelines or in accordance with local realities (Nagamine, et al., 2020).

The distribution of mortality and lethality in the region across each year evaluated may be influenced by population immunization levels and the predominant viral variant. The highest lethality observed in 2021 reached figures similar to those recorded worldwide, which ranged from 2,0% to 4,2%. In that year, Brazil experienced its second wave of COVID-19, with the Gamma variant predominating (Baethgen, et al., 2023). Additionally, social isolation measures were relaxed, while immunization efforts only began to take effect in the second quarter of that year, reaching only 60% of the population. Furthermore, the economically active population was required to return to work despite not yet being fully immunized (Lima, et al., 2023).

Following national and global trends in 2022, the southern region recorded more cases of COVID-19 compared to previous years, but mortality rates decreased (WHO, 2024). In 2022, the third wave of COVID-19 occurred due to the

emergence of the Omicron variant, which was more transmissible and may have contributed to the significant increase in cases (Baethgen et al., 2023). A meta-analysis showed that mortality rates caused by Omicron were half those of the Delta variant, indicating that although Omicron was more transmissible, it had a lower mortality rate (Ahmad et al., 2024). The reduction in mortality and lethality associated with Omicron is therefore related to milder symptoms linked to the variant, increased population immunity, and mass immunization efforts, which provided protection against complications and death from the disease (Renck, et al., 2024; Siqueira Junior, et al., 2021; Brito et al., 2023; Lima et al., 2023; WHO, 2024).

In 2022, nearly 80% of Brazilians completed the vaccination schedule (Razafindrakoto, et al., 2024). However, in 2023 and 2024, despite the continuation of vaccination campaigns, mortality rates in the southern region increased compared to 2022. This may be due to non-adherence to booster doses, influenced by a wave of vaccine denialism regarding its efficacy and safety (Baethgen et al., 2023). The complete vaccination schedule is associated with lower mortality rates compared to other vaccination statuses, regardless of age (Paludetto Junior et al., 2023). Supporting these findings, which emphasize the importance of vaccination in reducing COVID-19 mortality, a meta-analysis showed a 0,391 reduction in deaths from the Omicron variant among vaccinated individuals (Ahmad, et al., 2024).

It is also worth noting that data provided by the WHO on the global COVID-19 pandemic show that the number of weekly cases recorded at the beginning of 2023 was 1,3 million, while by the end of 2023, it had fallen to 246.000, and at the beginning of 2024, it was 70.000. Similarly, there were declines in the number of weekly deaths from 2022 to 2024. However, the WHO believes that the gradual reductions in the number of weekly cases reported by countries are due to decreased testing and reporting (WHO, 2024). Therefore, combining the mortality and lethality data for the Southern region between 2023 and 2024, as evidenced in this study, with the information that the worldwide reduction in cases and deaths may be related to decreased testing and reporting, highlights the need to maintain surveillance and preventive health measures related to COVID-19, including vaccination.

A limitation of this study is the lack of available data in the SUS Data System regarding the profile of COVID-19 cases, including those that progressed to death, broken down by factors such as gender, age group, race/color, hospital admissions, and the presence of associated health comorbidities. These factors have been shown in other studies to influence the pattern of disease-related deaths. Therefore, cross-referencing such data with mortality information could elucidate social and individual factors that contributed to the severity of lethality and mortality during the pandemic in the region, particularly in the state of Paraná, which recorded the highest number of deaths from the disease. Additionally, these data could help establish a profile of the most vulnerable populations to COVID-19-related death, thereby contributing to prevention and health promotion strategies in future pandemics. Although this study allowed for an assessment of the distribution of cases and deaths across different states and geographical regions, it was not possible to determine the prevalence of specific death profiles or whether factors such as sex, age, race/color, and comorbidities contributed to mortality in those states. This limitation could be addressed in future research focusing on the southern region.

5. CONCLUSION

It can be concluded that Covid-19 mortality and lethality rates were not homogeneous across the three states in the southern region. The distribution of deaths was also not proportional to the number of cases during 2021 and 2022. These findings underscore the importance and necessity of coordinating management of public health emergencies at the federal level. Additionally, they highlight the relevance of non-pharmacological prevention measures, as well as the critical of vaccines in controlling infection, reducing disease severity and decreasing mortality from Covid-19. Therefore, it´s essential to invest in health education campaigns aimed at the population to counteract vaccine denialism, which limits vaccination coverage and allows controlled diseases to resurface.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENTS

Unochapecó and the Coordination for the Improvement of Higher Education Personnel.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Ahmad, S. J. S., Degiannis, J., Borucki, J., & Pouwels, S., et al. (2024). Fatality rates after infection with the Omicron variant (B.1.1.529): How deadly has it been? A systematic review and meta-analysis. *Journal of Acute Medicine, 14*(2), 51–60. https://doi.org/10.6705/j.jacme.202406_14(2).0001

Baethgen, L. F., Veiga, A. B. G., Salvato, R. S., Carvalho, T. G., Rispoldi, T., & Shiefelbein, et al. (2023). SARS-CoV-2 laboratory surveillance during the first year of the COVID-19 pandemic in southern Brazil. *Journal of the Brazilian Society of Tropical Medicine, 56*, 1–9.

Bezerra, E. C. D., Santos, P. S., Lisbinski, F. C., & Dias, L. C. (2020). Spatial analysis of COVID-19 coping conditions: A proposal for a Brazilian Health Infrastructure Index. *Ciência e Saúde Coletiva, 25*(12), 4957–4967.

Brazil. (2024). *Coronavirus dashboard*. https://covid.saude.gov.br/

Brazil. (2024). *Weekly Covid-19 reports*. https://www.gov.br/saude/pt-br/assuntos/coronavirus/informes-semanais-covid19/covid-19-situacao-epidemiologica-do-brasil-ate-a-se-10-de-202

Brazilian Institute of Geography and Statistics. (2023b). *2022 Census: Paraná has the 12th highest density in Brazil, with 57.42 inhabitants per square kilometer*. https://www.aen.pr.gov.br/Noticia/Censo-2022-Parana-tem-12a-maior-densidade-do-Brasil-com-5742-habitantes-por-km-quadrado#:~:text=O%20Estado%20do%20Paran%C3%A1%20tem,m%C3%A9dia%20da%20regi%C3%A3o%20Sul%2C%2051

Brazilian Institute of Geography and Statistics. (2023). *Cities*. https://cidades.ibge.gov.br/brasil/sc/sul-brasil/panorama

Brito, A. S., Abreu, L. C., Estrada, D. A., Cavalcantti, M. P. E., Campos, M. F., & Carvalho, A. A. S. (2023). Three years of the Covid-19 pandemic: Comparative analysis of incidence, lethality, and mortality among the states of the southern region of Brazil. *J Hum Growth Dev., 33*(3), 1–13.

Covre, E. R., Pereira, N. D., Oliveira, N. N., Charlo, P. B., Oliveira, M. L. F., & Oliveira, R. R., et al. (2022). Spatial correlation of COVID-19 with intensive care unit beds in Paraná. *Public Health Journal, 56*(14), 1–11.

Klokner, S. G. M., Luz, R. A., Araújo, P. H. M., Knapik, J., Sales, S. S., & Torrico, G., et al. (2021). Epidemiological profile and predictors of risk factors for COVID-19 in the Southern region of Brazil. *Research, Society and Development, 10*(3), 1–13.

Lima, B. D. S., Fogaça-Rabito, L. B., Nishikawa-Yagi, M. C., Giorio-Dutra-Kreling, M. C., Rocha, L. F., & Eiko-Karino, M. (2023). Clinical-epidemiological profile of patients with COVID-19 admitted to a reference university hospital. *Quarterly Electronic Journal of Nursing, (70)*, 271–283.

Lopes, L. F. D., Faria, R. M., Lima, M. P., Kirchhof, R. S., Almeida, D. M., & Moura, G. L. (2020). Description of the epidemiological profile of COVID-19 in the Southern Region of Brazil. *Hygeia, 16*, 188–198.

Nagamine, L., Ferreira, G., Kruger, C., & Moura, R. (2020). Spread of COVID-19 in the land and coastal border areas of Brazil. *Tempo do Mundo, 23*, 204–233.

Oliveira Neto, T., Garcia, T. S. L., & Spinussi, E. (2020). COVID-19 pandemic, borders around the world and air transport in Italy *Pandémie de COVID-19, borders in the world and air transport in Italy*. *Open Edition Journals, (44)*.

Oliveira, R. A., Santos Neto, M., Ferreira, A. G. N., Pascoal, L. M., Bezerra, J. M., & Dutra, R. P., et al. (2022). Risk factors and spatial distribution of deaths from COVID-19: An integrative review. *Journal of Epidemiology and Infection Control, 2*(1), 1–21.

Paludetto Junior, M., Olak, A. S., Passarelli-Araújo, H., Susuki, A. M., Aschner, M., & Pott-Junior, H., et al. (2023). COVID-19 vaccination and case fatality rates: A case report in a Brazilian municipality. *Cadernos de Saúde Pública, 39*(3), 1–12.

Pan American Health Organization. (2023). *Coronavirus*. https://www.paho.org/pt/topicos/coronavirus?adgroupsurvey={adgroupsurvey}&gad_s

ource=1&gclid=Cj0KCQjwltKxBhDMARIsAG8KnqUhqgOs8298IgPcO6v0clVPK77C6ltZxad8v0chrRQFHrXqaEeLSZcaAlvaEALw_wcB

Paraná. (2024). *Coronavirus epidemiological report bulletin*. https://www.saude.pr.gov.br/Pagina/Coronavirus-COVID-19

Razafindrakoto, M., Roubaud, F., Castilho, M. R., Pero, V., & Saboia, J. (2024). Investigating the 'Bolsonaro effect' in the spread of the COVID-19 pandemic: An empirical analysis of observational data in Brazil. *PLOS ONE*, 1–29.

Razini, O. T., Bastos, L. S. L., Gelli, J. G. M., Marchesi, J. F., Baião, F., & Hamacher, S., et al. (2021). Characterisation of the first 25,0000 hospital admissions for COVID-19 in Brazil: A retrospective analysis of nationwide data. *The Lancet, 9*, 407–418.

Renck, E., Zipper, C. B., Fabrino Junior, M. R., Salgado, L. A. T., Rowe, A., & Helena, E. T. S. (2024). Vaccine effectiveness in preventing deaths in people with severe acute respiratory syndrome due to COVID-19 in Blumenau, 2021. *Epidemiology and Health Services, 33*, 1–12.

Rio Grande do Sul. (2024). *Rio Grande do Sul coronavirus panel*. https://ti.saude.rs.gov.br/covid19/

Santa Catarina. (2024). *Coronavirus: Information and bulletins*. https://www.coronavirus.sc.gov.br/boletins/

Santos-Melo, G. Z., Andrade, S. R., Cosme, K. O., Pereira, T. C. L., Monteiro, A. X., & Rineiro, G. M. A., et al. (2023). Importance and challenges of health surveillance in an international border region: A case study. *Health and Society, 32*(3), 1–10.

Silva-Sobrinho, R. A., Zylli, A., Silva, R. M. M., Arcoverde, M. A. M., Deschutter, E. J., & Palha, P. F., et al. (2021). Coping with COVID-19 in an international border region: Health and economy. *Latin American Journal of Nursing, 29*, 1–11.

Siqueira Junior, D., Morais, T. C., Portugal, I., Cavalcanti, M. P. E., Daboin, B. E. G., & Raimundo, R. D., et al. (2021). Trends in mortality and case fatality due to COVID-19 in the State of Paraná, Southern Brazil: Spatiotemporal analysis of one year of the pandemic. *J Hum Growth Dev., 31*(3), 1–14.

World Health Organization. (2024). *COVID-19 epidemiological update – 24 December 2024*. https://www.who.int/publications/m/item/covid-19-epidemiological-update---24-december-2024

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/139635