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COVID-19 pandemic in the State of Paraná: a spatio-temporal analysis of health indicators

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ABSTRACT. Monitoring COVID-19 health indicators allows the organization and implementation of policies to contain the disease. In this regard, the present study aimed to analyze the evolution of these indicators in the State of Paraná. This was a cross-sectional study, analyzing secondary quantitative data from the 22 Health Regions, of epidemiological bulletins from the Health Department of the state of Paraná, between March 2020 and March 2022. The variables Incidence Rate, Mortality Coefficient, and Lethality Coefficient were analyzed using descriptive statistics and presented through tables and thematic maps. The results showed that most of the Health Regions have high Mortality Coefficient and Incidence Rate after two years, especially the ninth Region (based in Foz do Iguaçu), which maintained a high incidence throughout the analyzed period. Lethality, on the other hand, showed a significant decrease within the Health Regions at the end of the period, demonstrating a decrease in the severity of the disease, which can be explained by the influence of the Vaccination Plan on this indicator. In addition, the first (based in Paranaguá) and second (based in Curitiba) health regions showed high indicators of Mortality and Lethality over time. The study highlighted the importance of monitoring health indicators to organize public policies to contain the disease in the State, especially the Vaccination Plan against COVID-19.

Keywords: COVID-19; public policy; spatio-temporal analysis.

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Introduction

Detected on December 31, 2019, in Wuhan, China, the new strain of Coronavirus, classified as SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2) and causing the infectious disease called COVID-19, has spread to several countries in an accelerated pace, being declared a Public Health Emergency of International Concern (PHEIC) on January 30, 2020 and classified as a pandemic by the World Health Organization (World Health Organization [WHO], 2020) on March 11 of that year.

COVID-19, transmitted from person to person through respiratory droplets or surfaces and objects contaminated by the SARS-CoV-2 virus, has clinical manifestations ranging from mild symptoms such as fever, dry cough, runny nose, loss of smell, and headache, to more severe symptoms, with the development of the characteristic Severe Acute Respiratory Syndrome (SARS), shock and death, with the elderly and individuals with comorbidities having greater predisposition to develop the severe forms (Ministério da Saúde, 2020).

Among its main characteristics, the SARS-CoV-2 virus has a high transmission speed, and each infected individual can transmit the disease to 2 to 3 other people. In addition, its incubation period is estimated at 7 days after the onset of symptoms, although studies have shown that transmission can occur even without the development of symptoms (Ministério da Saúde, 2020; Read, Bridgen, Cummings, Ho, & Jewell, 2020;Wang et al., 2020; Tong et al., 2020).

On February 26, 2020, the first case of COVID-19 was confirmed in Brazil and, on March 20, the Ministry of Health (MH) declared the state of community transmission through Ordinance no. 454, due to its accelerated propagation. From then on, the virus spread throughout the national territory, causing representatives of the three governmental spheres to implement measures to contain it (Ordinance no. 454, 2020).

On March 12, the disease reached the State of Paraná, making the monitoring of COVID-19 progression by state health authorities indispensable. In epidemic situations, this monitoring is carried out through the measurement of important indicators, such as the Incidence Rate, Lethality and Mortality Coefficients, to understand the characteristics of the disease and assist in the application of measures for its control

(Secretaria de Saúde do Estado do Paraná,(2020a; Ministério da Saúde, 2019). Therefore, the present study aimed to analyze the spatio-temporal evolution of COVID-19 health indicators in the 22 Health Regionals (HR) of the State of Paraná.

Method

This was a cross-sectional study, with a quantitative approach, which analyzes the evolution of health indicators in the State of Paraná, southern Brazil.

Data collection took place from the disclosure of the number of cases and accumulated deaths of COVID-19 by Health Region (HR) of Paraná, provided by the Epidemiological Bulletins from the State Health Department of Paraná (SESA/PR), between March 2020 and March 2022. Paraná comprises 22 regions divided territorially according to political-administrative health organization (Figure 1).

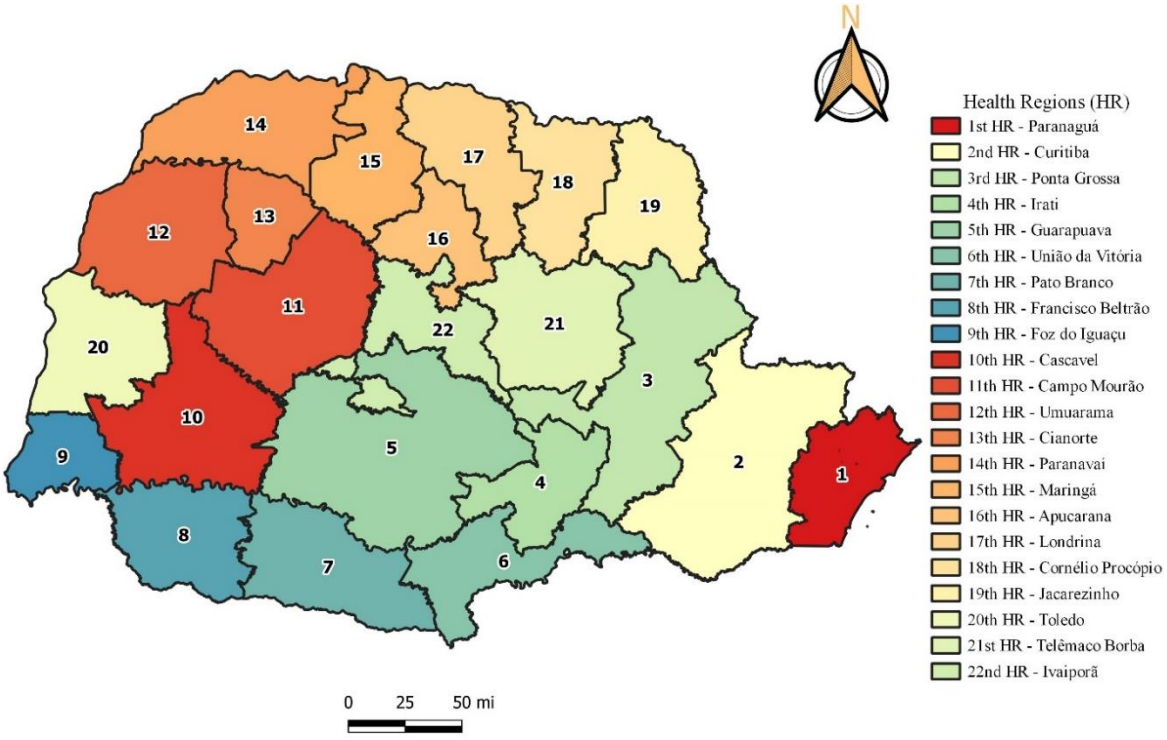


Figure 1. Map of the political-administrative organization of the State of Paraná in Health Regions (HR) with their respective headquarters, Paraná, 2022

Prepared by the authors, 2022.

Based on the number of confirmed cases and deaths, the following indicators were calculated: 1) Incidence Rate (IR), represented by the ratio between the number of confirmed cases of COVID-19 and the resident population, multiplied by 100,000; 2) Lethality Coefficient (LC), calculated by the ratio between the number of deaths from COVID-19 and the number of registered cases multiplied by 100; and 3) Mortality Coefficient (MC), measured by the ratio between the number of deaths from the disease and the resident population, in 100,000. For population data, estimated data from the database of the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística [IBGE], 2021) for the year 2021 were used.

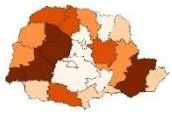
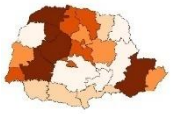
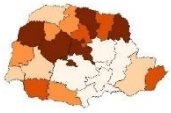
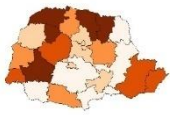
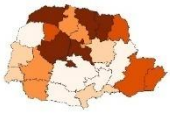
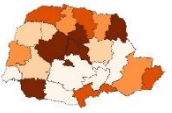
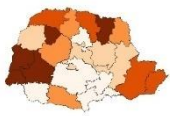
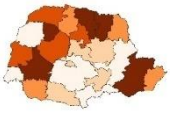
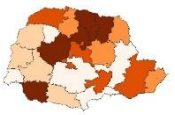
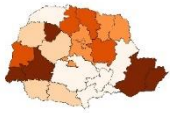
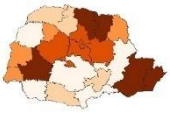
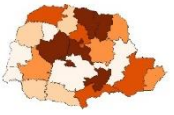
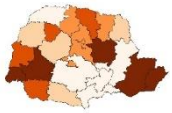
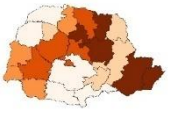
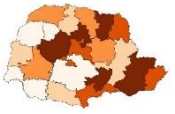
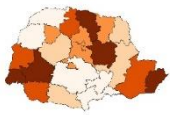
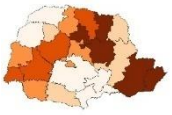
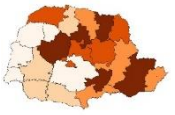
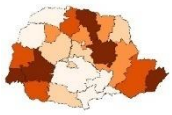
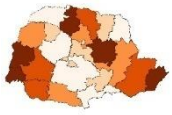
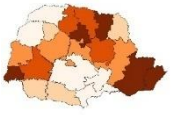
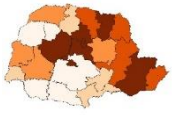
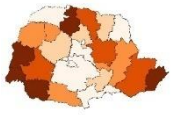
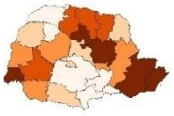
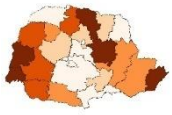
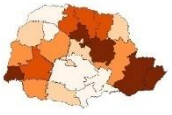
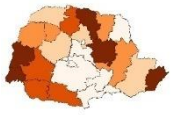
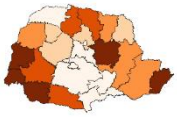
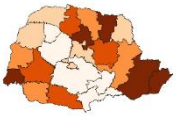
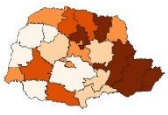
To calculate the health indicators, a base 10 constant was used (10^{no}). This constant, in addition to facilitating the understanding of the result, makes data comparable when dealing with populations of different sizes, allowing a proportional analysis of the evolution of the disease (World Health Organization [WHO], 2018).

Following collection, the data were tabulated and analyzed using descriptive statistical techniques and summarized representations on thematic maps with subsequent comparison with the available literature on the subject in question. The QGIS 3.10 software was used to build the maps, and for their analysis, the values were categorized into quintiles of 20%, allowing equal distribution of data across regions.

The research was developed in accordance with the norms of Resolution 466 of 2012, of the National Health Council (NHC) and the project was approved by the Human Research Ethics Committee under opinion No. 4.204.573/2020.

Results and discussion

The evolution of the COVID-19 pandemic was uneven among the health regions of the State of Paraná, a fact confirmed by the visualization of thematic maps presented over two years of analysis (Figure 2).

Date	Incidence Rate	Mortality Coefficient	Lethality Coefficient
March, 2020			
April, 2020			
May, 2020			
June, 2020			
July, 2020			
August, 2020			
September, 2020			
October, 2020			
November, 2020			
December, 2020			
January, 2021			
February, 2021			
March, 2021			
April, 2021			

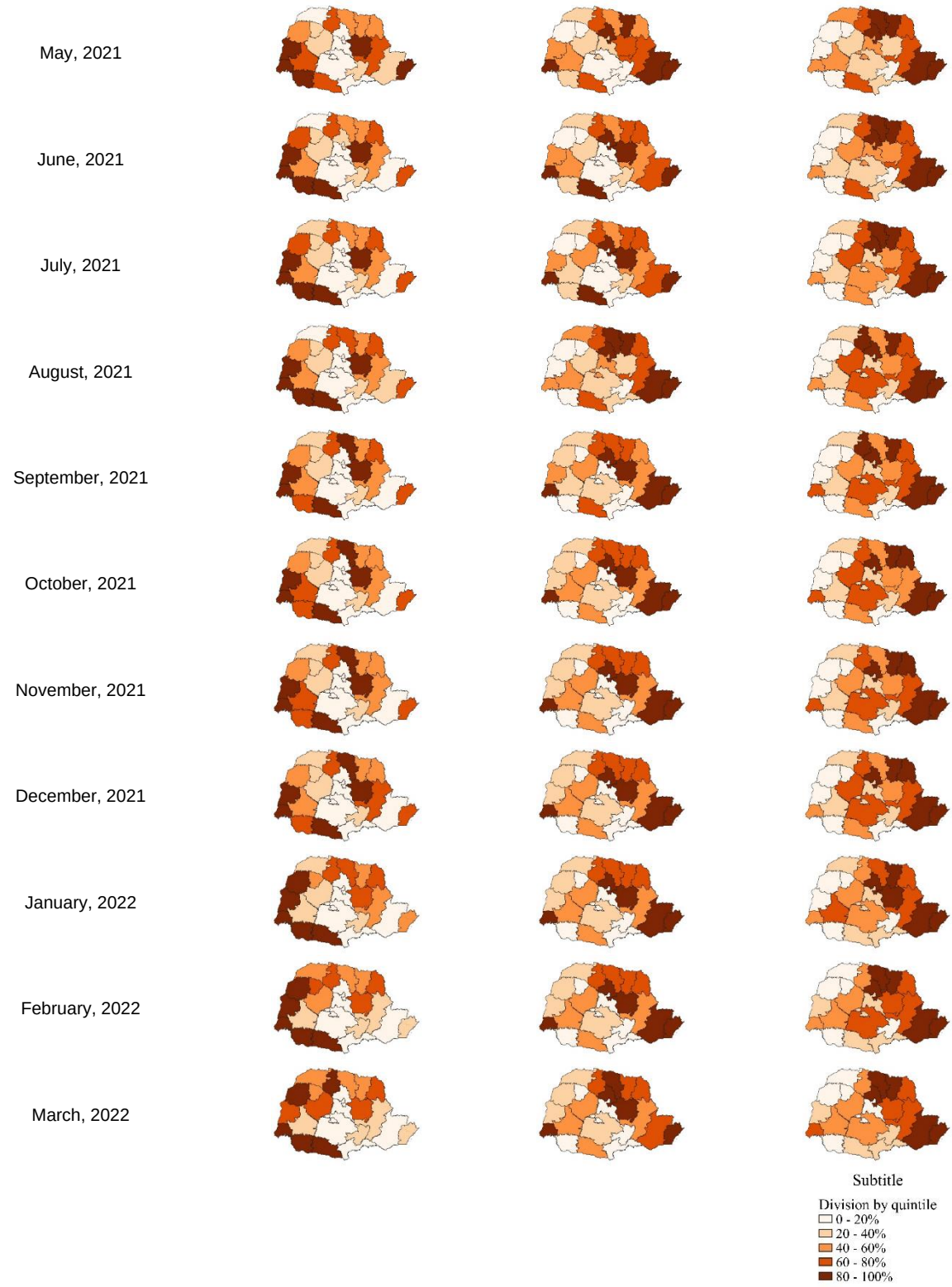


Figure 2. Evolution of the Incidence Rate, Mortality Coefficient and Lethality Coefficient of COVID-19 from March 2020 to March 2022 in the 22 Health Regions of the State of Paraná

Prepared by the authors, 2022.

Regarding the Incidence Rate of COVID-19 in the analyzed health regions, the following stands out: the 9th HR, which maintained values above the 4th quintile throughout the period; the 20th, 21st, 8th, and 7thHRs, which presented values above the 4th quintile (from June, July and August 2020 and February 2021, respectively), remaining high until the end of the period. Contrary dynamics are observed in the 1st and 2ndHRs, with a peak of the indicator in July 2020 (above the 5th quintile), and a gradual decrease from May 2021 in relation to the other regions analyzed.

The analysis of the Incidence of COVID-19 in Paraná must consider social, economic, and cultural characteristics of each region, which contribute to the accelerated propagation within regions. As an example, we can observe the case of the 9th HR, based in Foz do Iguaçu – a municipality that borders Paraguay and Argentina – in view of the high circulation of people due to several factors, such as: the willingness to natural attractions that make the region an international tourist hub; the work and trade relations characteristic in the region; and the use of public health and education services. Notably, Foz do Iguaçu represents the second most popular Brazilian destination for foreigners and the largest free zone in Latin America (Campos, 2017; Aikes & Rizzotto, 2018; Organização das Nações Unidas [ONU], 2020).

The same issue can be observed in the 20th HR, which includes the municipality of Guaíra, a free zone with Paraguay, with economic characteristics similar to Foz do Iguaçu, which reflect on the high incidence of the disease in these regions, since the highlighted territories have a strong influence on the other regions.

Another health indicator evaluated by the study was the Mortality Coefficient. For the Pan American Health Organization (2018), data on mortality in a given population represent a fundamental source of demographic, geographic, and cause-of-death information, being used to determine and monitor health priorities or goals.

The analysis of the MC in the State highlights the 1st, 2nd, 16th, and 18thHRs, which presented values above the 4th quintile, especially from July 2020 to the end of the study. Furthermore, the 21st HR showed a significant increase in July 2020, as did the 9th in September of the same year, remaining above the 4th quintile throughout the period, except in August 2021 (MC values in the 2nd quintile for the 21st HR and in the 3rd quintile for the 9th HR).

It is important to review the influence of the territory in the dynamics of the health indicators analyzed, as in the case of the 1st and 2ndHRs. In the first case, in addition to the 1st HR being close to the metropolitan region and covering the surrounding economic and tourist activities, its base is in the municipality of Paranaguá, in the port region of the State. Although its activities are primarily customs, there is a large circulation of workers, truck drivers, and travelers daily in the port terminals of the municipality – traffic of more than 4,000 people per day – (Governo do Estado do Paraná, 2020), which contributes to the spread of the virus in the region.

In the case of the 2nd HR, its resident population corresponds to approximately 32.07% of the population of Paraná. The headquarters of the 2nd HR is in the state capital, where the first cases were confirmed. Moreover, the capital is considered a national tourist spot, for its landscapes and commercial activities, in addition to having an international airport. These factors contribute to a high flow of individuals, which facilitates the transmission of COVID-19 in the region (Secretaria de Saúde do Estado do Paraná, 2021a; Instituto Brasileiro de Geografia e Estatística, 2021).

To organize the implementation of policies to contain the disease in the state territory, Paraná adopted a system for classifying the status of transmission risk, created by the MH. This system is based on Incidence and Mortality indicators, as follows: 1) Emergency (Red) – HR with Incidence or Mortality Coefficient 50% above the State indicators; 2) Attention (Yellow) – HR with Incidence or Mortality Coefficient between state indicators up to 50% above; and 3) Alert (Green) – HR with Incidence or Mortality Coefficient below the State indicators (Secretaria de Saúde do Estado do Paraná, 2020b).

Based on this classification system, Table 1 presents the epidemiological situation of the indicators of Incidence and Mortality of COVID-19, as well as the Lethality Coefficient after 2 years of confirmation of the first cases in the State.

Despite the 2 years of the pandemic, the indicators of Incidence and Mortality in Paraná, in relation to Brazil, and in the State Regional Health Departments, remain high. Most Health Regions (17) are classified within the Attention status in what regards incidence of cases. Regarding Mortality, 10 RSs are in the same classification. For both indicators, the 9th HR stands out among the regions with the highest risk (highest Incidence – 26,884.66/100,000 – and second highest Mortality – 429.12/100,000), given its geographical characteristics.

Moreover, the following Health Regionals presented Attention classification for both indicators at the end of the period evaluated: 1st (MC of 407.91/100,000 and IR of 21,156.41/100,000), 7th (MC of 372.35/100,000 and IR of 25,758.95/100,000), 15th (MC of 386.17/100,000 and IR of 25,164/100,000), 17th (MC of 398.24/100,000 and IR of 22,716.64/100,000), 18th (MC of 388 74/100,000 and IR of 22,369, 04/100,000), 19th (MC of 386.07/100,000 and IR of 23,665.77/100,000), and 21st (MC of 409.49/100,000 and IR of 23,752.83/ 100,000).

Table 1. Health indicators in Brazil, Paraná and in the 22 Health Regions of the State in March 2022.

Local	Headquarters	Incidence Rate	Mortality Coefficient	Lethality Coefficient
Brazil	-	14,024.31	309.16	2.20
Paraná	-	20,879.30	368.18	1.77
1st HR	Paranaguá	21,156.41	407.91	1.93
2nd HR	Curitiba	15,402.40	396.28	2.57
3rd HR	Ponta Grossa	22,145.76	366.62	1.66
4th HR	Irati	21,798.79	276.02	1.27
5th HR	Guarapuava	17,981.76	286.70	1.59
6th HR	União da Vitória	15,822.52	220.51	1.39
7th HR	Pato Branco	25,758.95	372.35	1.45
8th HR	Francisco Beltrão	26,613.11	276.97	1.04
9th HR	Foz do Iguaçu	26,884.66	429.12	1.60
10th HR	Cascavel	22,037.48	347.51	1.58
11th HR	Campo Mourão	23,564.16	345.55	1.47
12th HR	Umuarama	25,570.84	290.97	1.14
13th HR	Cianorte	23,505.45	224.31	0.95
14th HR	Paranavaí	23,072.98	287.30	1.25
15th HR	Maringá	25,164.03	386.17	1.53
16th HR	Apucarana	19,559.95	436.74	2.23
17th HR	Londrina	22,716.64	398.24	1.75
18th HR	Cornélio Procópio	22,369.04	388.74	1.74
19th HR	Jacarezinho	23,665.77	386.07	1.63
20th HR	Toledo	25,434.33	332.53	1.31
21st HR	Telêmaco Borba	23,752.83	409.49	1.72
22nd HR	Ivaiporã	20,264.55	260.93	1.29

values in blue represent Incidence Rate and Mortality Coefficient values that are above the respective state indicator, according to the risk classification system. To calculate these indicators, the denominator 10n was used. The values of Lethality Coefficient above the state indicator are also in blue, although the classification for this indicator is not adopted.

Finally, another indicator analyzed was the Lethality Coefficient, considered as a measure of disease severity, which expresses the ability of a disease or condition to cause death in affected individuals. The higher the lethality of a disease, the greater its severity in a given population (Gomes, 2015).

The analysis of LC highlights the 18th HR, which presents values in the 5th quintile from June 2020 to the end of the period and in the 16th from August 2020. In addition, the 1st, 2nd, and 19th HRs showed an increase in the indicator in August 2020, remaining above the 4th quintile until the end of the period - except for the 19th HR, particularly in March 2021, which showed a drop to the 3rd quintile.

At the end of the evaluated period, the Lethalities of the 1st (1.93%), 2nd (2.57%), and 16th RSs (2.23%) were above the state indicator (1.77%), with the 2nd and 16th also presenting LC above the national indicator (2.20%). Lethality was the only indicator that kept Paraná below the national reference.

Initially, the calculation of the Lethality Coefficient was not accurate because, as the indicator varies according to the number of individuals confirmed with the disease, the delay between the exam collection and the confirmatory result made the indicator unreliable. Often, the test result occurred after the event of death.

According to De Negri, Zucoloto, Miranda and Koeller (2020), another fact that initially led to inaccuracy of Lethality was related to the classification system adopted for testing individuals, as people with mild symptoms were not tested, leading to cases underreporting – characterized as the registration of cases below the lower limit (Ministério da Saúde, 2019)– influencing the calculation of the indicator.

For Melo et al. (2018), the factors contributing to case underreporting are mainly associated with the conduct of health professionals, the difficulties in the notification process, and the complex characteristics that lead to the difficulty in diagnosing the disease and/or condition.

These underreporting problems can affect the assessment of the three health indicators analyzed. Regions with low testing and in which the tests are directed only to critically ill patients tend to generate higher lethality indicators as they do not consider the real number of infected people (Souza, Paiva, Leal, Silva & Santos, 2020). This also occurs in the evaluation of the Incidence.

In addition, problems such as the standardization of the testing to be applied, inadequate transport, the type of methodology used to analyze the exams, the detection of the ideal moment for sample collection and the accuracy of the results made the initial diagnostic confirmation of COVID-19 a challenge all over the world (Magno et al., 2020; França et al., 2020), even though these problems can still be identified in some regions.

Furthermore, death records compromise and failure can affect the knowledge of the real magnitude of mortality from COVID-19. In the pandemic, the poor completion of the Death Certificate (DC), reinforced by the precarious or non-existent medical care during the terminal phase of the disease, and the fragile working conditions in some regions, were highlighted as a harmful factor for information accuracy (França et al., 2020).

In Brazil, the delay in carrying out tests and results, as well as cases and deaths underreporting, hinder the pandemic progression monitoring, the planning of resources to face it, as well as the evaluation of the effectiveness of the control measures to be adopted by the governments, leading to false conclusions regarding the disease control in a given territory and generating contradictory suppression measures among the different levels of government (Prado et al., 2020; Werneck & Carvalho, 2020), with this reality being extended to the State of Paraná.

Regarding the measures adopted in the state of Paraná to fight the disease, the following are highlighted: mandatory use of masks, suspension of activities generating agglomerations, mandatory teleworking for risk groups (elderly, people with chronic diseases, pregnant and lactating women), considering that mortality was notably higher in this population (Decree no. 4.230, 2020). These measures were implemented mainly in the first year of the pandemic, since at that time there was no immunizing agent to control the disease.

In January 2021, the State publishes the State Vaccination Plan against COVID-19, following the guidelines of the Ministry of Health National Immunization Program (PNI), as the main response measure to face the pandemic (Secretaria de Saúde do Estado do Paraná, 2021b). The Plan implemented with other measures to fight it aimed to control the health crisis and to reduce the severity of the disease, which was high by that time.

Initially, the progress of the implementation of the Immunization Plan faced obstacles such as the federal government's bet on just one immunizer (AstraZeneca/Oxford), delaying the beginning of the campaign, causing fear and insecurity in the population due to the spread of fake news regarding vaccine effectiveness, as well as the chronic underfunding of the health sector that impacted the purchase and distribution of inputs (Fleury & Fava, 2022; Nobre, Guerra & Carnut, 2022).

Regarding health funding, in 2020 Paraná received R$1.1 billion intended for actions to fight COVID-19, corresponding to only 2.29% of total State expenditure. Of this amount, 715 million were allocated to health (1.45% of total expenses in Paraná). In 2021, the amount of expenses with the pandemic dropped to 889 million, with 652 million for health (1.32% of the total amount). These values are much lower than expected for a health crisis, especially in 2021, in view of the current Vaccination Plan (Governo do Estado do Paraná, 2022).

However, even though faced with political and organizational weaknesses, the results of the present study showed a reduction in the severity of the disease after one year of the beginning of the Vaccination Plan against COVID-19, evidenced by the decreased lethality in most of the State Health Regions. This finding evidences the need to encourage the implementation of the vaccination policy throughout the territory.

Conclusion

The results presented by the research encourage the continuity of monitoring of the indicators throughout the territory, to organize the implementation of coping actions, as well as the advancement of the Vaccination Plan against COVID-19. Although there was a reduction in the lethality of the disease at the end of the period evaluated, Incidence and Mortality still present worrying data among the Health Regions, compared to state and national parameters.

In this regard, an in-depth analysis of the effect of the implementation of the Vaccination Policy against COVID-19 on the State's health indicators is required, as a proposal for a future study, to fight the spread of the disease and reduce its severity.

As a limitation of the study, we highlight data obtained from secondary databases, which may be underreported, impacting the analyses results.

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