ANALYSIS OF COVID-19 MORTALITY AND CASE-FATALITY IN A LOW- INCOME REGION: AN ECOLOGICAL TIME-SERIES STUDY IN TOCANTINS, BRAZILIAN AMAZON

Abstract

Introduction: The State of Tocantins is inserted in the vulnerable context of the Brazilian Amazon. Its first confirmed case of COVID-19 was reported in the state capital, Palmas, on March 18, 2020, by a traveller returning from Fortaleza, an urban city in the country northeast. The situation worsened; in more than a year after registering the first case, the state reached 12,868 accumulated new cases and 211.7 deaths per 100,000 inhabitants. **Objective**: Analyze the mortality and case-fatality of COVID- 19 in Tocantins, Brazil. **Method:** It is an ecological study of population-based time-series analysing information about cases and deaths by COVID-19 in the state of Tocantins from March 2020 to March 2021. **Results**: During the examined period Tocantins was affected by 140,975 cases of people infected by COVID-19; 2,032 of them died due to Coronavirus disease. There was the formation of two possible waves, the first from March to November 2020 and the second wave from December 2020 to March 2021. **Conclusion:** The second wave presented more distressing circumstances, with increasing trends for lethality, mortality, and incidence. The prevention, surveillance, and control actions of COVID-19 cases in Tocantins have been managed to mitigate the effects of the pandemic. However, efforts are still needed so that the trends in lethality, mortality, and incidence show decreasing trends, and the pandemic can be under control in the region.

Keywords: COVID-19. Mortality. Incidence. Trends. Tocantins.

Introduction

The COVID-19 pandemic has beaten Brazil hardly; it ranks second in deaths, behind the United States of America. This South American country is confronting one of the most complex hospital and health crises ever (Abreu 2021). Its first confirmed COVID-19 case was reported on February 26, 2020 (Brasil 2021); since that date, Brazil has exhibited critical epidemiological circumstances in its enormous territorial dimension, ranging in severity from region to region (Lobo *et al.* 2020).

These regional differences in population density, access to health services, age, and socioeconomic factors have accentuated inequities, mainly impacting the country's most impoverished areas, such as the North (Coelho *et al.* . 2020). These imbalances also observed in the failures of social protection in the region, such as lack of immediate assistance from health and effective integrated control measures, have been identified as contributors to mortality and more elevated social vulnerability (Brasil 2003). Furthermore, there are gaps concerning medical professionals in this territory, in which the medical residency positions reach 1.9% and only 3.4% of specialists (Scheffer *et al.* 2011).

The State of Tocantins is inserted in this vast, vulnerable context of the Brazilian Amazon. Its first confirmed case of COVID-19 was reported in the state capital, Palmas, on March 18, 2020, by a traveller returning from Fortaleza, an urban city in the country northeast (Governo do Estado de Tocantins, 2020). A month later, the state authorities reported its first death due to this disease (Secretaria de Saúde de Tocantins, 2020a). The situation worsened; in more than a year after registering the first case, the state reached 12,868 accumulated new cases and 211.7 deaths per 100,000 inhabitants (Brasil 2021).

The mortality rate is one of the main characteristics that differentiate the coronavirus from the SARS and MERS outbreaks. Given the fluctuations detected in the incidence and lethality of COVID-19 (Pimentel 2020), it is relevant to study and understand regional factors that affect the contagion and spread of this virus.

Therefore, this study analyzed the mortality, incidence and case-fatality of COVID- 19 in Tocantins, Brazil, from March 2020 to March 2021.

Method

It is an ecological study of population-based time-series (Abreu and Siqueira 2021) analysing information on cases and deaths by COVID-19 in the state of Tocantins (Figure 1), the northern region of Brazil.
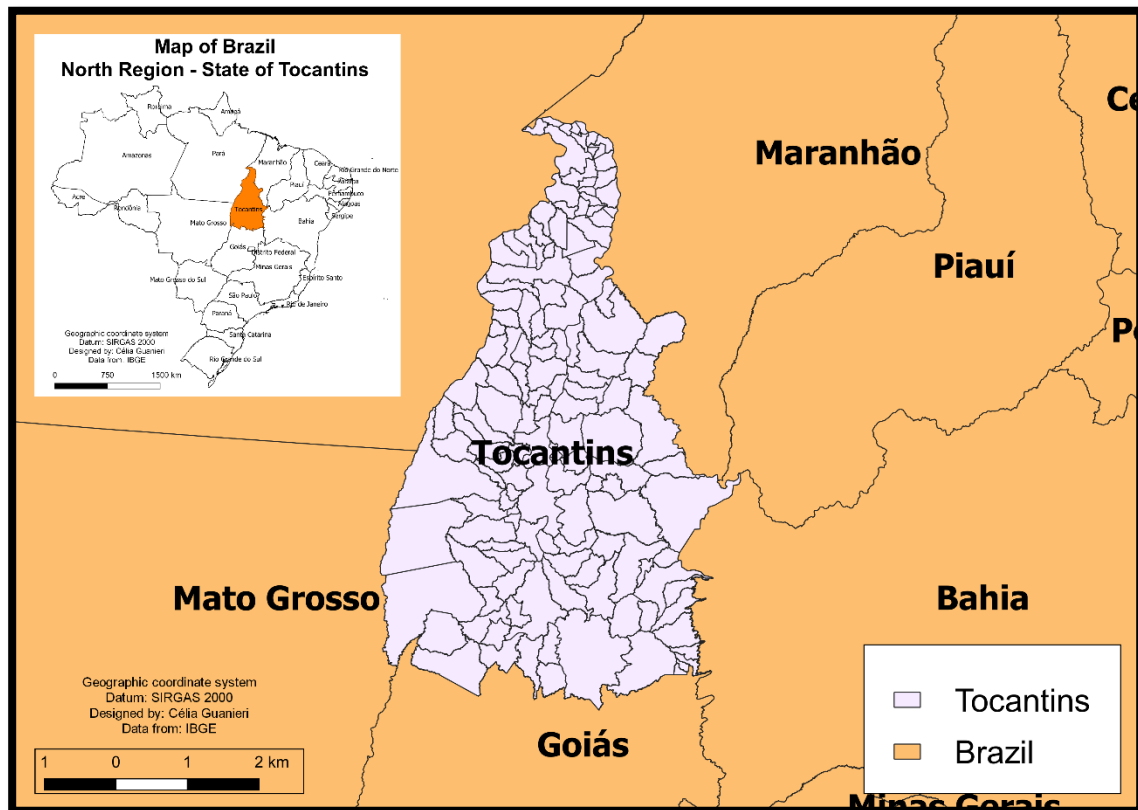

Figure 1 - Map of Tocantins and its location in the Brazilian territory.

The source of information is a platform from the Tocantins State Health Department, with official data of public use (*Secretaria de Saúde do Estado de Tocantins, 2021b*), it contains data provided by the municipal health departments to inform the COVID-19 epidemic status.

From March 2020 to March 2021 were recorded a total of 140,975 accumulated cases and 2,032 deaths by COVID-19. All cases and deaths with laboratory, clinical or epidemiological confirmation of COVID-19 were included. The cases were classified according to the test date and according to death date, those without a date of death were excluded. Two different

researchers collected data to avoid collection bias. Then, the extracted information was organized in an Excel spreadsheet for further analysis. The database was updated on May 1, 2021.

The incidence (A) and mortality rates (B) by 100,000 inhabitants and the case-fatality (C) (%) were determined with the following equations:

$$\text{(A)} \ \frac{\text{Number of cases}}{\text{Population}} \times 100{,}000 \quad \text{(B)} \ \frac{\text{Number of deaths}}{\text{Population}} \times 100{,}000 \quad \text{(C)} \ \frac{\text{Number of Deaths}}{\text{Number of cases}} \times 100$$

The population used for calculations was obtained from the Federal Court of Accounts (TCU population). It corresponded to the resident people in Tocantins and was estimated in 1,572,866 inhabitants for 2019 (Datasus 2021).

For trends analysis, the period was split into two waves, the First Wave from March to November 2020 and the second wave from December 2020 to March 2021. The first wave finished with the lowest mortality rate in November, suggesting the end of a first wave in the curve.

The Prais-Winsten regression model for population mortality rates was used to build time series and determine the mortality and case fatality trend (Antunes and Cardoso 2015). The following values were calculated: probability (p), and Daily Percent Change - DPC, considering a 95% level significance, as illustrated in the following equation:

$$\text{DPC} = [-1+10\beta]*100\%$$
$$\text{IC } 95\% = [-1+10\beta min]*100\%; \ [-1+10\beta max]*100\%$$

The STATA 14.0 software (College Station, TX, U.S. 2013) was used for statistical analysis. The effective reproductive number (Rt) was estimated using R studio software EpiEstim package (Cori *et al.* 2013), version 2.2.4, a time-varying reproduction number for epidemics developed by Thompson and colleagues (2019). We used a mean serial interval of 2.97 days with a mean standard deviation of 3.29 days, as described in previous studies (Prete *et al.* 2021, Ali *et al.* 2021).

Results

The sociodemographic characteristics and key information of the hospital infrastructure of the State of Tocantins are described in Table 1.

Table 1 - Sociodemographic characteristics of the state of Tocantins, Brazil.

Sociodemographic characteristics	Description
Region[*]	North
Number of municipalities[*]	139 municipalities
State's capital[*]	Palmas
Territorial extension[*] (2020)	277,423.630 km²
Demographic density[*] according last census, 2010[*]	4,98 inhabitants /km²
Monthly household income per capita[*]	1.060 reais
Human Development Index (HDI), according last census, 2010[*]	0.699
Average number of people per household[**](2019)	3 people
Number of basic health units[***]	427 units
Total Hospital Beds[****] (June 22, 2021)	hospital beds
Clinical beds - COVID-19 adults	169 clinical beds
Occupancy rate of Clinical beds - COVID-19 adults	50% clinical beds occupied
Number of COVID-19 ICU beds	189 ICU beds
Number of COVID-19 ICU beds occupied	163 ICU beds occupied
Occupancy rate of COVID-19 ICU beds	90% of ICU beds occupied

Source: *Brazilian Institute of Geography and Statistics (IBGE, 2021).
** Sistema IBGE de Recuperação Automática - SIDRA
*** Cadastro Nacional de Estabelecimentos de Saude (CNESNet)
**** Secretary of Health of State of Tocantins.

Figure 2 illustrates that total number of cases and fatal victims due to COVID-19, throughout the period studied, there were identified 140,975 cases (A). The graphs B and C evidence two possible waves, the first occurred in 2020 from March to November, and the second wave from December 2020 to March 2021.

During the first wave, the highest peaks of cases and number of fatal victims happened in August and September 2020, and the second wave was marked by the significant increment of cases and deaths in March 2021 (Figure 2, B and C)
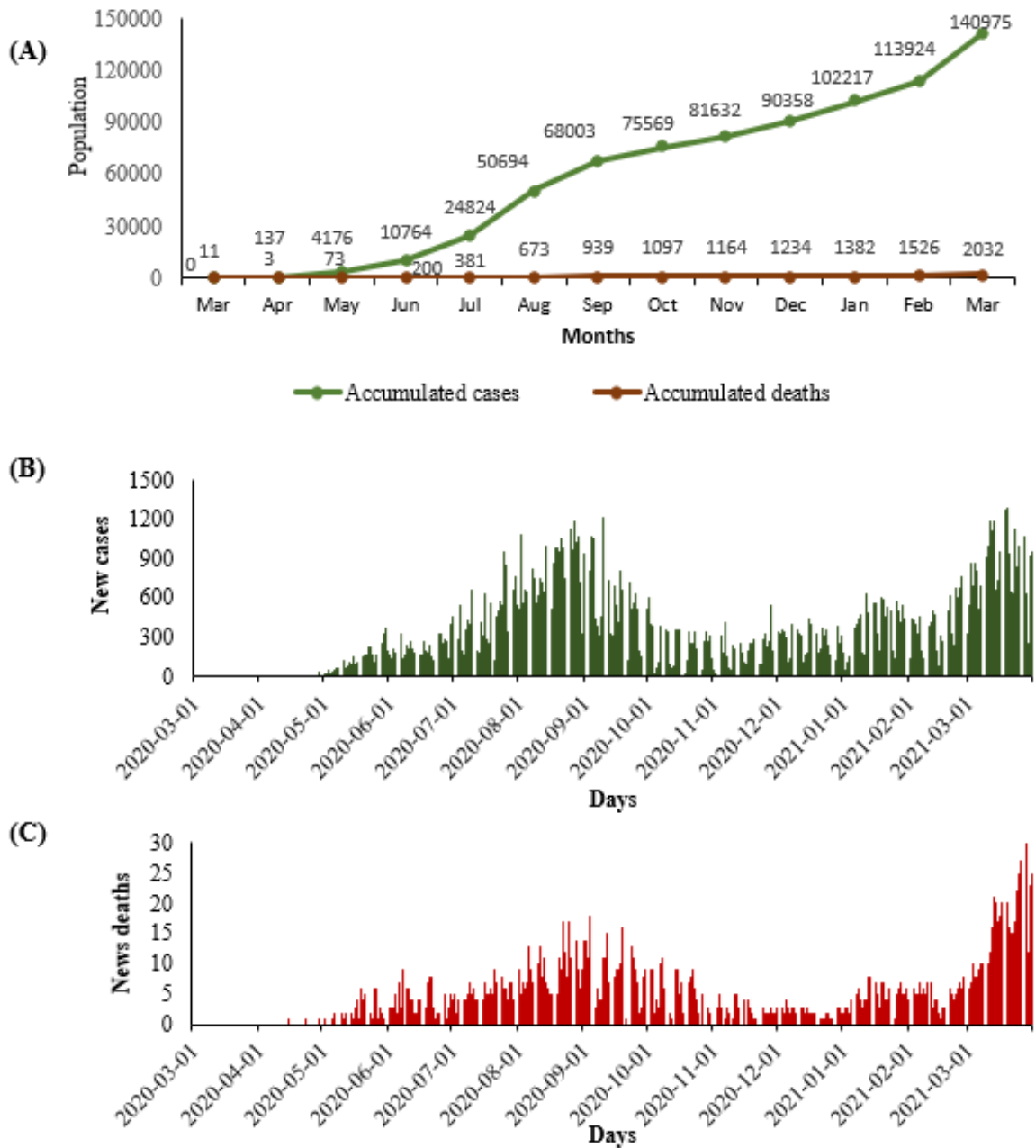
Figure 2 - Number of cases and deaths accumulated (A), new cases (B) and deaths (C) daily and by COVID-19 in the State of Tocantins from March 2020 to March 2021.

Source: Secretary of Health of the State of Tocantins, Brazil.

Gross case fatality, mortality and incidence rates were distributed by month and illustrated in Figure 3.

(A)

1st Wave | 2nd Wave

Case-fatality (%)

0, 2.38, 1.73, 1.93, 1.29, 1.13, 1.54, 2.09, 1.10, 0.80, 1.25, 1.23, 1.87

Mar Apr May Jun Jul Ago Sep Oct Nov Dec Jan Feb Mar

Months

(B)

Mortality rate (per 100,000 inhabitants)

0, 0.19, 4.45, 8.07, 11.51, 18.56, 16.91, 10.04, 4.26, 4.45, 9.41, 9.15, 32.17

Mar Apr May Jun Jul Ago Sep Oct Nov Dec Jan Feb Mar

Months

(C)

Incidence rate (per 100,000 inhabitants)

0.7, 8.01, 256.79, 418.85, 893.91, 1644.77, 1100.47, 481.03, 385.47, 554.78, 753.97, 744.31, 1719.85

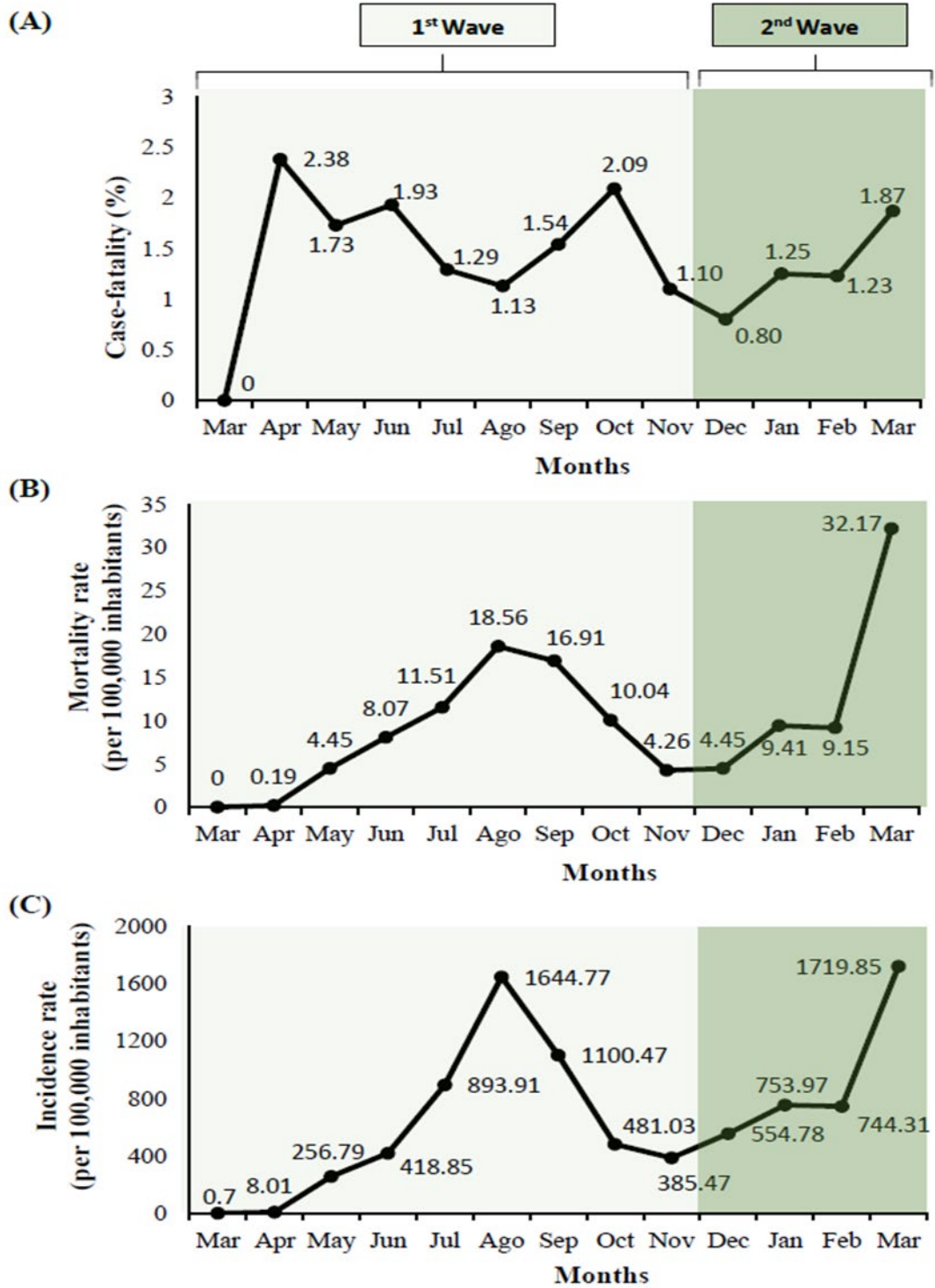Mar Apr May Jun Jul Ago Sep Oct Nov Dec Jan Feb Mar

Months

Figure 3 - Gross rates of case-fatality percentage, mortality and incidence rates by 100,000 inhabitants of COVID-19 in Tocantins state from March to November 2020 and December.

The highest lethality rate in the period (2.38%) was observed in April 2020, and the highest mortality rates (32.17 deaths per 100,000 inhabitants) and incidence (1719.85 cases per 100,000 inhabitants) were observed in March 2021 (Figure 3). The second wave of COVID-19 in Tocantins presented a more startling scenario, with increasing trends in case-fatality, mortality, and incidence ($p<0.05$) (Table 2).

Period	DPC (CI 95%) Case-fatality	p	Fatality Trends	DPC (CI 95%) Mortality	p	Mortality Trend	DPC (CI 95%) Incidence	p	Incidence Trend
1st Wave (March - November 2020)	-0.14 (-0.37: 0.08)	0.213	Flat	0.28 (-0.04:0.59)	0.083	Flat	2.68 (1.49: 3.88)	<0.001*	Increase
2nd Wave (December 2020 - March 2021)	0.75 (0.35:1.15)	<0.001*	Increase	1.94 (1.37:2.50)	<0.001*	Increase	1.19 (0.75:1.62)	<0.001*	Increase

Table 2 – Prais-Winsten regression estimates and DPC of case-fatality (%), mortality and incidence rate by 100,000 inhabitants of COVID-19 in the State Tocantins.

DPC – Daily Percent Change (%); CI 95% – Confidence interval 95%; p-value – probability of statistical significance. *Statistical difference detected by the Prais -Winsten regression test, $p<0.05$.
Source: Cases, deaths, and population extracted from the Department of Health of State of Tocantins, Brazil.

Figure 4 indicates the behaviour and estimate value of Effective Reproduction Number (RT) of COVID-19 during the examined period. The Rt had indexes above one (1) in most of the months. During the first wave late August showed the Rt with values predominantly below 1. While during the second wave there were fluctuations in the Rt, with values below 1 seen at the end of March 2021.
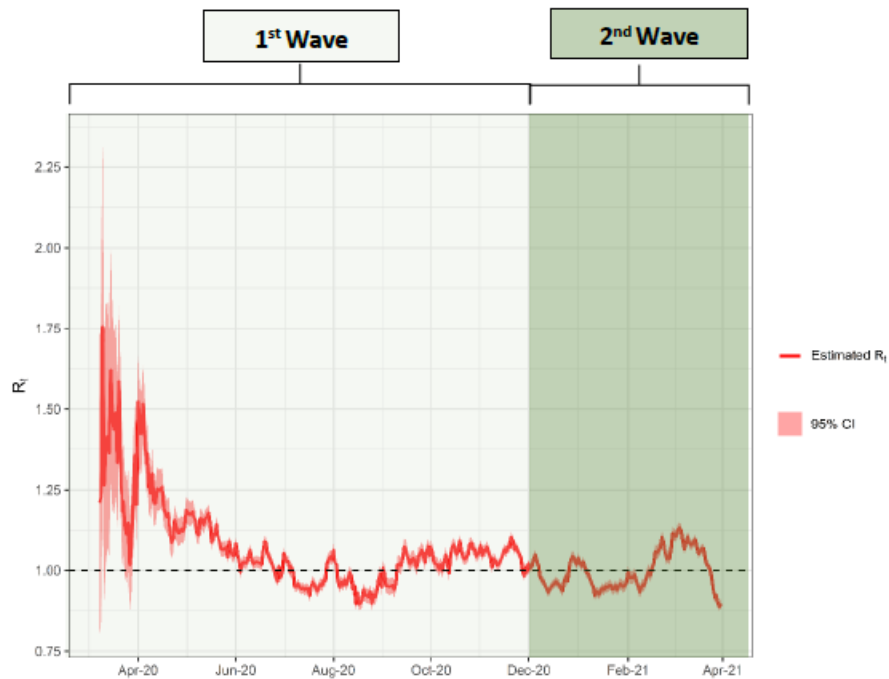
Figure 4– Effective Reproduction Number (RT) estimated of COVID-19 during March,6, 2020 to March 31, 2021, Tocantins, Brazil.

CI = Confident Interval. Rt = Effective Reproduction Number.

Discussion

From March 2020 to March 2021, Tocantins was affected by 140,975 cases of people infected by COVID-19; 2,032 of them died due to Coronavirus disease. During this period, there was the formation of two possible waves. The second wave presented more distressing circumstances, with increasing trends for lethality, mortality, and incidence with their respective Daily Percent Change (DPC): 0.75%; 1.94%; and 1.19%.

Furthermore, in March 2021, the highest incidence (1719.85 cases per 100,000 inhabitants) and mortality rate (32.17 deaths per 100,000 inhabitants) of the entire period studied were observed. The DPC allows a better understanding of the pandemic behaviour compared to

the rates. The mortality and fatality rate remained flat during the first wave, but the incidence had an increasing trend.

Its highest case-fatality rate marked the onset of the pandemic in this state (2.38%), confirmed in April 2020, when the first deaths of victims (n=3) of COVID-19 were reported. This result matches the COVID-19 case-fatality published by the State Government of Tocantins at the beginning of the pandemic, with a lethality record of 2.03% in May 2020 (Secretaria de Saúde do Estado de Tocantins, 2020c). It is noted that this fatality is lower than that found in other states such as Piauí (9.09%), Pernambuco (7.35%), and São Paulo (5.97%), during the 13th epidemiological week (Souza *et al.* 2020).

According to the COVID-19 Observatory report of Fundação Oswaldo Cruz on the first six months of the pandemic, Tocantins had one of the highest incidence rates in the country and in August 2020 reached the third-highest rate in the northern region, with trends increasing incidence and mortality rates (Fiocruz 2020). Similar results were found in the current research; during the first wave, August 2020 had peaks of incidence (1644.77 cases per 100,000 inhabitants) and mortality (18.56 deaths per 100,000 inhabitants). Despite the high increments in the indicators of incidence and mortality described in August 2020, it was the month of March 2021 that revealed the most alarming rates of incidence (1,719.85 cases per 100,000 inhabitants) and mortality (32.17 deaths per 100,000 inhabitants), almost doubled the number of deaths of the worst month during the first wave.

In March 2021, the Fundação Oswaldo Cruz issued a special bulletin warning on a simultaneous worsening across Brazil of the various indicators, with an increase in the number of cases and deaths of COVID -19, the maintenance of high levels of incidence of severe acute respiratory syndrome, high rates of test positivity and hospital overload. During this period, all states in the northern region, including Tocantins, had occupancy rates of Covid-19 ICU beds for adults above 80% (Fiocruz 2021a).

The high rates indicate that even after a year of a pandemic, the state of Tocantins, as well as Brazil, has been facing a challenging scenario to control the spread of COVID-19; the second wave had more distressing circumstances, with increasing trends for lethality, mortality, and incidence, with their respective DPC : 0.75%; 1.94%; and 1.19%. The DPC allows a better understanding of the pandemic behaviour compared to the rates. The mortality and fatality rate

remained flat during the first wave, but the incidence had an increasing trend. Fatality and incidence had a growing trend during the second wave.

Several factors may have contributed to this scenario, such as carnival and the infection with new variants. The high peak of cases and deaths observed during the Second Wave (in March 2021) happened in the month after the carnival holidays of February. The official carnival was cancelled (Governo do Estado de Tocantins, 2021a). Still, people gathered in the streets and private parties, which benefited the spread of the virus. During this period, the P1 (Manaus) variant of SARS-COV-2 was also detected for the first time, presenting greater transmissibility (Governo do Estado de Tocantins 2021b).

Trends in lethality, mortality, and increasing incidence at the end of the second wave, with the Rt number greater than one (1) verified between mid-February and March, indicate that the pandemic is still out of control, so efforts must be redoubled to contain the spread of SARS-COV-2 in this region and minimize future consequences. Hence, it is imperative to analyse the pandemic behaviour curves and understand the context behind them to make decisions and reduce the negative impact.

Like other states in the country's northern region, Tocantins is an endemic area for other infectious ailments, presenting symptoms similar to COVID-19. There is evidence of co-infection of SARS-CoV-2 with dengue (Quental *et al.* 2021). This syndemic context makes the detection and treatment of COVID difficult in the region. Tocantins also has deficiencies in access to health, and 93% of its population depends on the National Health System (Secretaria de Saúde do Estado do Tocantins 2019).

This state is the newest federative unit in Brazil, created in 1988, contributes approximately 0.5% to the national gross domestic product, being one of the states that contributes the least (IBGE 2021). Its geographical location is a kind of crossroads. There is a vast interchange through highways that lead to cities in the North, Northeast, and central-west regions (IBGE 2017), facilitating the spread of the COVID-19 virus.

According to the last census carried out by the Instituto Brasileiro de Geografia e Estatística (IBGE 2021), the demographic density of Tocantins is 4.98 inhabitants/ km2; in contrast, the average number of people per household in this region is three people per household (Sidra 2019). There is evidence that the high incidence of COVID-19 is also affected by the number of people per residence (Rozenfeld *et al.* 2020). High infection rates are associated with

many individuals living per household (Maroko *et al.* 2020); besides, people have isolation limitations (Smith *et al.* 2020). Under these circumstances, this situation primarily affects the population living in Palmas, the capital city.

In addition, data from the health secretary revealed that 7,886 indigenous people and 6,551 individuals of African descent (Quilombos) communities live on the banks of the rivers in houses where a high number of individuals congregate. Inhabitants of different remote regions use the boat transport through the rivers of the Amazon area (Ramirez 2020).

Tocantins is a state with high social vulnerability. Conversely, it was one of the first states to present a contingency plan to face COVID-19. Likewise, they created a crisis committee with authorities representing each of the powers, control and security bodies, and health authorities and professionals. These initiatives were carried out to debate and seek joint actions and strategies to minimize the impact of the pandemic (Cunha 2020).

Brazil does not have a homogeneous strategy to manage the pandemic of COVID-19. The state governments are accountable for planning and executing non-pharmacological and distancing strategies (Touchton 2021). In Tocantins, prevention initiatives were implemented before the first case of COVID-19 was reported in the state (Tocantins 2020a), and social distancing measures were adapted to reduce the risk of transmission. Immediately after confirming the first case, the local authorities declared a state of public calamity, including restrictions on non-essential commerce activities (Tocantins 2020b). The measures were stricter in Palmas, the most populated urban area. (Palmas 2020a). The number of beds was increased from 163 to 467 for the exclusive treatment of COVID-19, from April 2020 to April 2021, health professionals were hired, and personal protective equipment was made available (Secretaria de Saúde do Estado de Tocantins, 2021a)

The vaccination program plan against COVID-19 was created following the national guidelines; the priority groups included indigenous people, afro-descendant communities (Quilombos), and traditional riverine communities (Secretaria de Saúde do Estado de Tocantins, 2021c).

It must be highlighted that Tocantins, suffers health services constraints at regular times, and currently, they are dealing with a crisis that requires an urgent response. The actions of the leaders of this federative unit to apply prevention, surveillance, and control measures are key elements to minimize the spread of the virus SARS-CoV-2, mainly because the fatality,

mortality, and incidence rates are highly dependent on socioeconomic factors and local health infrastructure.

Even though this study analysis is limited to March 2021, it is essential to mention that according to the FIOCRUZ observatory (Boletim- July 14, 2021b), the occupancy rate of intensive care beds in Tocantins has dropped to 75%. Still this percentage is high, but one of the factors that may have influenced this improvement is the immunization process, with 718,000 people vaccinated.

The mandatory use of masks and distancing measures must remain to mitigate and restrain the effects of the pandemic in this Amazon territory. It is required to monitor mortality, lethality, and incidence indicators and develop further studies comparing those indicators before and after vaccination.

Limitations

It must be taken into account; the covid tests were only carried out on people with clinical manifestations of Covid-19. Furthermore, cases were classified according to the Test date, which does not reflect the initial date of symptom events. The deaths related data is counted based on the previous day, but there may be cases of a delay in the notification.

As the pandemic is still in evolution, all the data examined in this research correspond to partial analysis.

Conclusions

The first wave showed decreasing lethality (%) and mortality (per 100,000 population) with increasing trends in incidence rates, with a Daily Percent Change of 2.68%. However, the second wave had a more shocking aspect, even after one year of the pandemic. All indicators (case-fatality, mortality, and incidence rates) showed increasing trends, with a high peak of incidence (1719.85 cases per 100,000 inhabitants) and mortality (32.17 deaths per 100,000 inhabitants) observed in March 2021.

During the study period, the prevention, surveillance, and control actions of COVID-19 cases in Tocantins have been managed to mitigate the effects of the pandemic. However, efforts are still needed so that the trends in lethality, mortality, and incidence show decreasing trends, and the pandemic can be under control in the region.

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