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Impact of COVID-19 on cutaneous leishmaniasis trend in Araguaína, Tocantins, Brazil

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ABSTRACT. Cutaneous leishmaniasis (CL) is a serious parasitic disease caused by protozoa of the genus Leishmania, transmitted by the bite of infected sandflies. This study analyzes the time series of CL in the municipality of Araguaína, Tocantins, Brazil, between 2016 and 2023, focusing on the impact of the COVID-19 pandemic. Data from the Notifiable Diseases Information System (SINAN) were used and statistical analyses of segmented regression and interrupted time series were applied. The pandemic significantly affected CL control programs, resulting in a sharp drop in diagnoses and underreporting of cases. In Araguaína, the incidence of CL increased until 2019, followed by a stabilization at low levels during the pandemic period. However, Tocantins as a whole showed a more pronounced reduction, suggesting greater effectiveness of control measures at the state level. The study highlights the importance of strengthening awareness and vector control campaigns to mitigate the impacts of CL, especially in vulnerable regions. It is concluded that CL control requires an integrated approach that considers the specific socioeconomic and environmental conditions of each region.

Keywords: Cutaneous leishmaniasis; COVID-19; time series; Legal Amazon.

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Introduction

Cutaneous leishmaniasis (CL) is a parasitic disease caused by protozoa of the genus *Leishmania*, transmitted by the bite of infected sandflies. Clinical manifestations range from recurrent lesions, which can evolve into permanent deformities, to the mucosal form, which frequently affects the mucous membranes, leading to serious complications if left untreated. CL is considered a serious public health problem, particularly in endemic regions such as Brazil, where thousands of cases have been reported annually over recent decades, disproportionately affecting vulnerable populations. (Almeida, et al., 2020).

The distribution of CL in Brazil is strongly influenced by environmental and socioeconomic factors, such as deforestation, unplanned urbanization, and human migration to endemic areas. Large-scale infrastructure projects, such as dams and highways, have also been associated with increased disease incidence, as they alter sandfly habitats and facilitate their adaptation to urban and peri-urban settings. Furthermore, limited vector control measures and insufficient health education campaigns contribute to the persistence of high incidence rates (Cunha & Ferreira, 2018; Werneck & Maguire, 2020).

The diagnosis of CL is based on clinical-epidemiological methods, complemented by laboratory tests, such as Montenegro's intradermal test and direct parasitological examination. Treatment is still predominantly based on pentavalent antimonials, despite the associated adverse effects and the increasing resistance observed in some areas. Recent studies have investigated the use of therapeutic alternatives, such as amphotericin B and new compounds, especially in refractory cases (Romero & Boelaert, 2021). However, ensuring access to treatment in rural and remote areas continues to be a major challenge, aggravated by the lack of infrastructure and low capacity for early diagnosis (Carvalho et al., 2001).

The COVID-19 pandemic has had a substantial impact on cutaneous leishmaniasis control programs. The overload of health systems, combined with the prioritization of pandemic response actions, in led to the interruption of surveillance and vector control activities in several endemic regions. Consequently, there was a significant reduction in the number of diagnoses and treatment of CL during the pandemic period, worsening clinical cases and contributing to underreporting of the disease (Luna et al., 2021). Additionally, the global economic crisis associated with the pandemic further affected access to treatment, widening health disparities, especially in vulnerable communities (Goto & Lindoso, 2020).

In terms of control and prevention, the most effective strategies include an integrated approach that involves epidemiological surveillance, vector control, early diagnosis, and appropriate treatment. The sustainability of these actions, however, depends on intersectoral cooperation that integrates health, environment, and urban development (Barbosa et al., 2022). The adoption of a One Health approach has been proposed as a promising solution to address CL, given its zoonotic nature and the complex interactions between human, animal, and environmental health (Vazquez-Prokopec et al., 2021).

The implementation of robust public policies, involving not only strengthening diagnostic and treatment networks but also targeted health education for vulnerable populations, is essential. Awareness campaigns on preventive measures, such as the use of repellents and housing protection, play a critical role in reducing exposure to the vector. In addition, the development of more effective vaccines and therapies remains a priority for the control of cutaneous leishmaniasis in Brazil (Souza et al., 2023).

Material and methods

This study is based on a quantitative approach to analyze the incidence of cutaneous leishmaniasis (CL) in the municipality of Araguaína, Tocantins, Brazil, from 2016 to 2023 (Figure 1). Descriptive and inferential analyses, such as segmented regression and interrupted time series, were used to evaluate the impact of the COVID-19 pandemic on the dynamics of the disease.

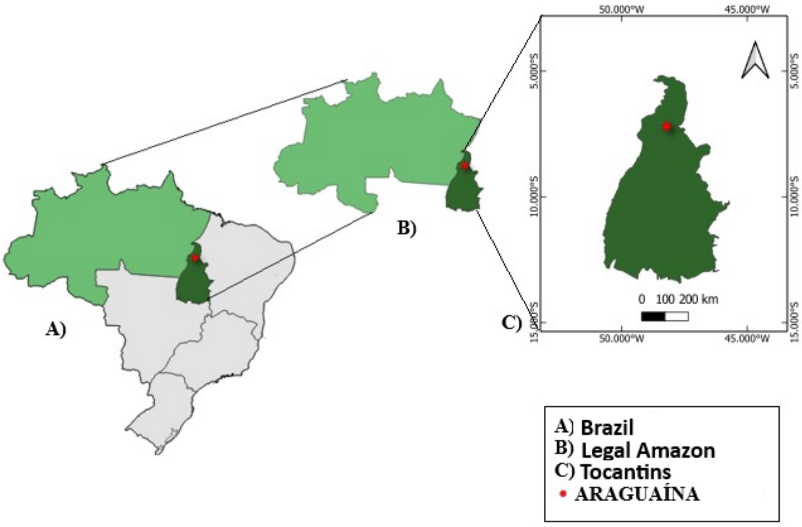

Figure 1. Araguaína, Tocantins state, Brazil.

Type of study

This is an ecological time series study that analyzed the monthly variation in the incidence of confirmed CL cases over eight years, with special attention to the period from 2020 to 2022, considered the interruption interval related to the COVID-19 pandemic.

Data source

The data used in the study were extracted from the Notifiable Diseases Information System (SINAN), referring to notifications of CL in the municipality of Araguaína, Tocantins, between January 2016 and December 2023. The estimated population of Araguaína was considered constant at 171,301 inhabitants to calculate the incidence per 100,000 inhabitants. In addition, the data were stratified by month and year, allowing a detailed analysis of monthly and annual fluctuations (IBGE, 2024).

Incidence calculation

Monthly incidence of CL was calculated using the formula:

Incidence = (number of monthly cases / estimated population) x 100,000

This formula was applied to each month between 2016 and 2023, allowing the construction of a monthly time series. Incidence rates were then adjusted for comparison with the average incidence for Tocantins and ~~in~~ Brazil, with aiming to identify potential deviations in local trends.

Descriptive analysis

Initially, a descriptive analysis of the incidence data was performed, with calculation of measures of central tendency (mean and median) and dispersion (standard deviation). The objective of this analysis was to describe the annual and monthly variation in the incidence of CL in Araguaína, especially during the pandemic period.

Segmented regression

Segmented regression was applied to identify possible changes in trends in CL incidence over time. For this purpose, the study period was divided into two segments: pre-pandemic (2016-2019) and post-pandemic (2020-2023). The segmented regression model was fitted to assess the change in the orientation of the time series and detect the magnitude of the impact of COVID-19 on the trend of leishmaniasis cases. The overall finding of the model was:

$$Yt= \beta 0+\beta 1Tt+\beta 2Dt+\epsilon t$$

Where:
Yt: Monthly incidence of CL at time t;
Tt: Time in months since the beginning of the series;
Dt: Dummy variable indicating the pandemic period (0 before 2020; 1 from 2020 onwards);
ϵt: Random error term.

The analysis was performed with Python software, using libraries specialized in regression analysis and time series.

Interrupted time series

Interrupted time series analysis was used to assess the direct impact of COVID-19 on the incidence of CL between 2020 and 2022. This method allows analyzing whether there was a significant change in the disease trend after the onset of the pandemic. The interrupted time series model was adjusted with the inclusion of an indicator variable for the pandemic period, defining an interruption between January 2020 and December 2022.

The model discovery was adjusted as follows:

$$Yt = \beta 0 + \beta 1Tt + \beta 2It + \beta 3(Tt\times It) + \epsilon t:$$

Where:
Yt: Monthly incidence of CL at time t;
Tt: Time in months from the start of the observation period;
It: Indicator variable (0 before the intervention in January 2020; 1 from January 2020 to December 2022);
Tt × It: Interaction term representing the change in trend after the intervention (pandemic);
ϵt: Error term.

The period from 2020 to 2022 was defined as the pandemic interval as it corresponds to the most critical phase of the COVID-19 public health emergency in Brazil. This period was marked by major disruptions in disease surveillance systems, access to health services, and continuity of control strategies for neglected tropical diseases such as CL. Several studies have reported a substantial reduction in case notifications, interruption of vector control campaigns, and underreporting in hyperendemic areas throughout this period (LUNA et al., 2021; LIMA et al., 2022). Therefore, delimiting this time frame allows for an accurate assessment of the epidemiological changes attributable to the pandemic, in line with the methodological standards for interrupted time series analyses.

Hypothesis testing

To compare the incidence of cutaneous leishmaniasis before and after the pandemic, a paired t-test was used within each region, comparing the means of the pre-pandemic (2016–2019) and pandemic/post-pandemic periods (2020–2023). This test is appropriate for evaluating changes over time in dependent samples.

Additionally, the Student's t-test for independent samples was used to assess whether the mean incidence differed significantly between Araguaína and the state of Tocantins. A *p*-value less than 0.05 was considered statistically significant, indicating that the observed differences were unlikely due to chance. Confidence intervals of 95% were also calculated for the mean incidence.

Statistical tools

All analyses were performed using Python, with libraries such as pandas for data manipulation, matplotlib and seaborn for graphical visualizations, and statsmodels and scipy for statistical analyses. Graphical visualization included the use of line graphs and control diagrams in order to represent trends and monthly variations in the incidence of leishmaniasis.

Study limitations

This study has some limitations. First, the quality of the data depends on the adequate and complete reporting of cases in SINAN, and there may be underreporting, especially during the COVID-19 pandemic. Second, the population of Araguaína was considered constant over the years, which may not reflect population growth and, consequently, influence the calculation of incidence. Finally, the analysis of the impact of the pandemic was restricted to the period from 2020 to 2022, making it impossible to fully assess the long-term effects.

Ethical aspects

This study used publicly available secondary data, and did not require submission to the Research Ethics Committee, in accordance with CNS Resolution No. 510/2016.

Results

During the study period from 2016 to 2023, the state of Tocantins recorded a progressive reduction in the absolute number of cutaneous leishmaniasis (CL) cases, especially after the onset of the COVID-19 pandemic. In contrast, the municipality of Araguaína exhibited fluctuations in the number of cases, with a notable increase in 2019. Specifically, Araguaína reported approximately 18 to 20 cases annually from 2016 to 2018, followed by a peak of 44 cases in 2019. From 2020 onward, a decline was observed, with the number of cases stabilizing between 16 and 20 per year until 2023 (Figure 2). In the broader context, Tocantins showed higher absolute case counts in the early years of the series (above 400 annual cases), which progressively declined to under 250 cases per year after 2021. These figures reflect the regional dynamics of CL transmission and reinforce the differentiated impact of public health measures across state and municipal levels (Brazil, 2025).

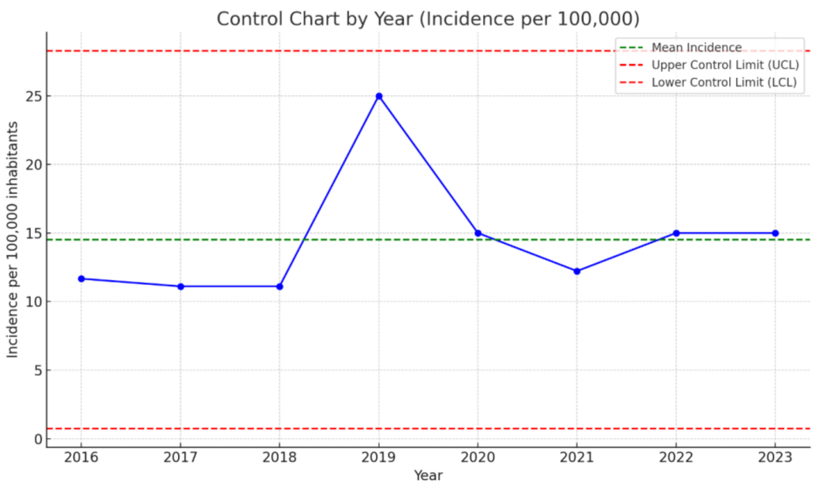

Figure 2. Control diagram for incidence cases of CL in the municipality of Araguaína between 2016 and 2023.

The incidence of Leishmaniasis in Araguaína, as shown by the blue line, was relatively stable from 2016 to 2017, with values around 12 cases per 100,000 inhabitants. In 2018 and 2019, there was a significant increase, with the incidence reaching a peak of almost 26 cases per 100,000 inhabitants in 2019. From 2020 onwards, an abrupt decrease was observed, which coincided with the onset of the COVID-19 pandemic, and the incidence stabilized around 10-12 cases per 100,000 inhabitants in subsequent years (2020-2023) (Figure 3).

The green line represents the overall incidence of Leishmaniasis in the state of Tocantins. In 2016, the incidence was already higher than that of Araguaína, around 26 cases per 100,000 inhabitants, and maintained a slight downward trend until 2019. From 2020 onwards, a sharper decline in incidence is observed in Tocantins, especially after 2021, with a significant reduction until 2023. The significant decline in Tocantins, especially in 2022 and 2023, is captured by the sharply declining green line, suggesting a more substantial reduction in incidence in the state compared to Araguaína (Figure 3).

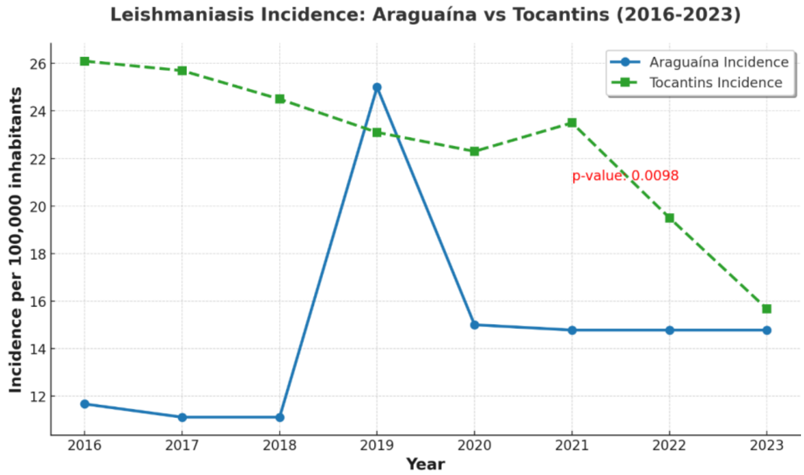

Figure 3. Analysis of the incidence of CL in Araguaína and the state of Tocantins.

At the beginning of the period (2016-2017), Tocantins had a higher incidence of Leishmaniasis compared to Araguaína. In 2019, the two regions converged, with Araguaína showing a steep increase, momentarily surpassing the incidence rate of Tocantins. After the pandemic, however, Araguaína showed a stabilization around 10-12 cases per 100,000 inhabitants, while Tocantins continued to show a more significant decrease. The difference in behavior in the trends is statistically significant, as indicated by the p-value of 0.0098, which suggests that the reduction in incidence in Tocantins was more pronounced and statistically different from that of Araguaína (Figure 3).

During this period, the incidence of leishmaniasis showed moderate variation until 2018, with values fluctuating between 10 and 12 cases per 100,000 inhabitants. From 2018 onwards, the incidence showed a sharp increase, culminating in a peak in 2019 with around 24 cases per 100,000 inhabitants. The segmented regression (red line) for this period indicates a gradual upward trend, adjusting smoothly until the peak in 2019. This suggests that, until this point, the incidence of leishmaniasis was rising steadily, especially in 2018 and 2019 (Figure 4).

From 2020 onwards, there was a significant decline in incidence, dropping rapidly to around 10 cases per 100,000 population. The segmented regression line (red line) fits to capture this steep decline, showing a clear change in direction. The trend indicates that, after the onset of the COVID-19 pandemic, there was a significant change in the incidence patterns of the disease.

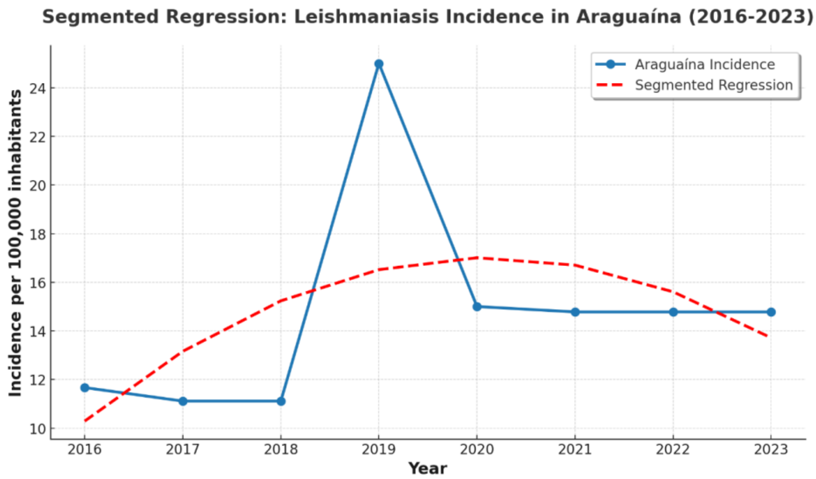

Figure 4. Segmented regression for the incidence of CL in the municipality of Araguaína under the influence of the COVID-19 pandemic.

From 2020 to 2023, incidence appears to have remained stationary at around 10 cases per 100,000 population. This stabilization at lower levels suggests a new trend of low incidence, possibly still influenced by the pandemic or the ongoing impacts on public health systems. The segmented regressioncaptures this change, with a slight downward slope, showing that incidence did not return to previous (pre-COVID-19) levels until 2023.

Figure 5 presents the result of an interrupted time series analysis, illustrating the profound impact of COVID-19 on the dynamics of CL in Araguaína: while the pre-pandemic period (until 2019) showed a statistically significant upward trend, the advent of the pandemic in 2020 triggered an immediate and statistically significant reduction in the reported incidence level. Subsequently, the disease trajectory exhibited a statistically significant change in slope, shifting to a pattern of stabilization or even slight decline, in sharp contrast to the previously observed pattern of increase.

According to the analysis before the pandemic, the incidence of Leishmaniasis was increasing steadily, during the COVID-19 period, the incidence showed a stationary trend and then showed a slight decrease. The post-COVID-19 trend (red line) indicates that incidence rates have stabilized, diverging from the increasing trend that was present in the period before the pandemic.

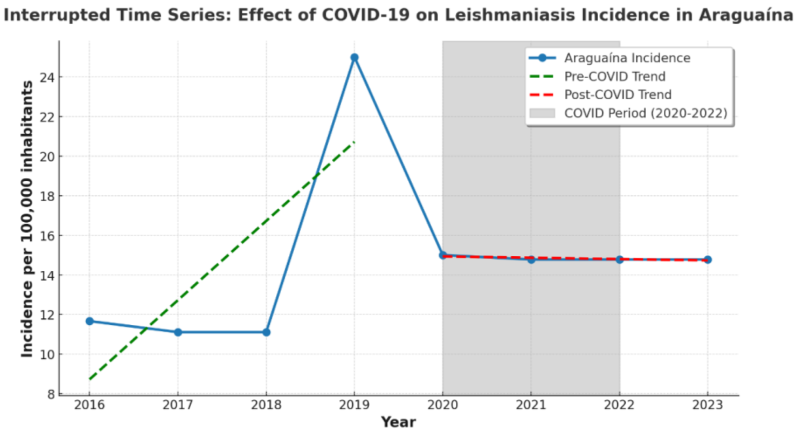

Figure 5. Interrupted time series for cases of CL under the influence of the COVID-19 pandemic.

Discussion

The incidence of cutaneous leishmaniasis (CL) in Araguaína and the state of Tocantins between 2016 and 2023 presents a complex interaction between geographic, environmental, entomological and social factors, which contribute to the increase or decrease in cases of the disease. Data analysis shows that the COVID-19 pandemic had significant impacts on control strategies, resulting in a stabilization of the incidence in Araguaína and a more pronounced reduction in Tocantins. In this context, it is essential to discuss the factors that directly influence the epidemiology of the disease in the region, in light of the scientific literature (Gomes de Jesus et al., 2024).

The geographic location of Araguaína, in a transition zone between the Cerrado and the Amazon biomes, creates an environment conducive to the transmission of CL. The destruction of forest areas, intensified by agricultural expansion and disorderly urbanization, favors the spread of CL vectors, such as *Lutzomyialongipalpis*, which adapts well to peri-urban and urban environments (Lima et al., 2017; Oliveiraet al.,2020; Vasconcelos et al., 2024). This adaptation is facilitated by the presence of organic matter and infected dogs, which increases the risk of transmission. A recent study highlighted the influence of climatic variables, such as humidity and temperature, on the proliferation of vectors, especially in transition areas such as Tocantins, where the Amazon and Cerrado biomes cohabit (Fernandes et al., 2022; Cavalcante e Gomes 2025).

The adaptation of *Lutzomyialongipalpis* to the urban and peri-urban environment is one of the main factors that perpetuates the transmission of CL. The vector finds ideal conditions for its reproduction in areas with poor sanitation, accumulation of garbage and presence of domestic dogs, which are the main reservoirs of *Leishmania* (Brazil, 2017). A study conducted in northern Tocantins demonstrated that peri-urban and rural areas have a high density of *sand flies*, corroborating the need for interventions aimed at controlling these vectors in areas of greater socio-environmental vulnerability (Gomes et al., 2023). This reinforces the importance of environmental management policies that aim to reduce the proliferation of vectors in areas of greater risk (Machado et al., 2025).

The COVID-19 pandemic has had a significant impact on CL surveillance and control, especially in hyperendemic areas such as Araguaína. The diversion of human and financial resources to combat COVID-19 resulted in a temporary interruption of vector control campaigns and a decrease in the diagnosis of CL cases (Lima et al., 2022). Furthermore, the population's fear of seeking medical care during the pandemic may have led to underreporting of cases, which would explain the stabilization observed in the graphs for Araguaína after 2020 (Souza et al., 2023). A recently published study corroborates the hypothesis that underreporting of neglected diseases, such as Leishmaniasis, was exacerbated during the pandemic, especially in regions with poor health infrastructure (Gomes et al., 2023).

Socioeconomic inequalities are a crucial factor in the epidemiology of Leishmaniasis. The peri-urban areas of Araguaína, which are home to populations in situations of social vulnerability, are the most affected by CL, due to poor sanitation conditions and proximity to areas of vegetation, where vectors proliferate (Torres & Matos, 2019). Studies indicate that poverty, combined with limited access to health services, significantly contributes to the perpetuation of the disease in regions such as northern Tocantins (Nunes et al., 2019). The association between social vulnerability and the incidence of Leishmaniasis in Tocantins is reinforced by an ecological analysis conducted between 2011 and 2020, which identified high-risk areas in municipalities with low socioeconomic indices (Silva et al., 2024).

Studies that use spatial analysis, such as that of Silva et al. (2024), highlight the importance of indicators of social vulnerability and income inequality in understanding the distribution of Leishmaniasis. Regions with greater poverty, where populations have less access to health services and face greater exposure to vectors, record a higher incidence of the disease. However, even in cities with good socioeconomic indicators, such as Araguaína, peripheral areas continue to concentrate high rates of Leishmaniasis, demonstrating the internal disparity within municipalities (Oliveira et al., 2019; Souza et al., 2023).

The data show that, although Tocantins showed a more pronounced reduction in the incidence of CL after 2020, Araguaína maintained a stabilization at lower levels, suggesting that control efforts were less effective or more impacted by the pandemic. The literature reinforces the need for integrated control strategies, which include environmental management, continuous surveillance of cases, and health education campaigns for the most vulnerable populations (World Health Organization [WHO], 2021). In addition, the continuity of vaccination and treatment campaigns for infected dogs, combined with vector control, is essential to reduce disease transmission (Gontijo & Melo, 2004).

The identification of risk areas, as reported by Silva et al. (2024), can help direct public health policies to the most vulnerable regions, ensuring an efficient allocation of resources. The use of tools such as spatial analysis and predictive modeling can contribute significantly to the planning and execution of interventions aimed at controlling the spread of leishmaniasis in regions at higher risk.

Cutaneous leishmaniasis continues to represent a major public health challenge in Araguaína and the state of Tocantins. Geographic, environmental, and socioeconomic factors contribute to the perpetuation of disease transmission, and the impact of the COVID-19 pandemic has exacerbated the challenges faced by health authorities. Effective control of CL will require a continuous and integrated effort, including identifying risk areas, strengthening vector control campaigns, and combating social inequalities that perpetuate the population’s vulnerability to neglected diseases.

Conclusion

The state of Tocantins showed a continuous and more significant decline in the incidence of Leishmaniasis after 2019. In contrast, Araguaína experienced a sharp increase in 2019, followed by a stabilization at lower levels during the pandemic period. The difference between the municipality and the state is statistically significant, suggesting that disease dynamics and control measures differed between these areas.

The interrupted time series indicates a clear impact of the COVID-19 pandemic on the incidence of leishmaniasis. Before the pandemic, the trend was upward, but from 2020 onwards there was a sharp decline, followed by a stabilization at lower levels. This pattern reflects both the direct effect of the pandemic on case reporting and the possible interruption of disease control programs. To restore adequate levels of leishmaniasis control, it may be necessary to reinforce disease surveillance and control efforts in the post-pandemic period.

The state of Tocantins as a whole showed a more favorable trend, with a sharper drop in the incidence of Leishmaniasis after the pandemic, reflecting more effective control of the disease. The municipality of

Araguaína experienceda peak in Leishmaniasis in 2019, followed by a decline after the pandemic, with a stabilization at lower levels from 2020 onwards. The impact of the pandemic was significant, and recovery to pre-pandemic levels of disease control has not yet been observed until 2023. The statistically significant difference between Araguaína and the state of Tocantins suggests that interventions and efforts to control Leishmaniasis may have varied between cities and the state as a whole, with less effective results in the municipality of Araguaína.

However, with the implementation of measures such as rapid testing for leishmaniasis and active surveillance in high-risk areas, the municipality may have increased its detection rate. These measures were not implemented by a significant portion of the state's municipalities, suggesting a risk of undercounting existing cases in these regions.

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