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# Epidemiological and temporal modeling of Hansen's disease in Maranhão: trends, seasonality, and predictive analysis (2019–2024)



Artigo Original

Flor de Maria Araújo Mendonça Silva[1]; Yuri Alfredo Araújo Mendonça Silva[2]; Marcia Rodrigues Veras Batista [3]; Nielson Valério Ribeiro Pinto [4]; Igor Thiago Pinheiro Passos[5]; Jonathan Araujo Queiroz [6]; Fabrício Brito Silva [7] ; Adriana Sousa Rêgo[8]

Correspondência:
CEUMA University, São Luís, Maranhão, Brazil
1.Doctorate in Public Health - E-mail: floragyh@gmail.com
2.Master in Health Programs and Services Management - E-mail: yurimendonca33@icloud.com
3.Master in Health Programs and Services Management - E-mail: márcia.veras2932@gmail.com
4.Master in Health Programs and Services Management - E-mail: nielson_valerio@hotmail.com
5.Medical Student, CEUMA University - E-mail: igor_passosp@hotmail.com
6.Doctorate in Electrical Engineering - E-mail: jonathan.queiroz@ceuma.br
7.Doctorate in Remote Sensing- E-mail: abricio.brito@ceuma.br
8.Doctorate in Public Healthl - E-mail: adriana004723@ceuma.com.br

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*Resumo*

*A Hanseníase é uma doença infecciosa causada pelo Mycobacterium leprae (M. leprae), persistente em diversas regiões do mundo, principalmente nos países em desenvolvimento, onde há prevalência de pobreza e baixa cobertura dos serviços básicos de saúde e saneamento como é o caso do Brasil. O presente estudo é epidemiológico do tipo ecológico de série temporal, cujo objetivo foi analisar a tendência da taxa de detecção de hanseníase no estado do Maranhão, Brasil, no período de 2019 a 2024. Os dados dos casos novos de hanseníase foram obtidos do Sistema de Informação de Agravos de Notificação (SINAN), disponibilizado pelo Ministério da Saúde dos casos notificados de hanseníase no Maranhão entre 1º de janeiro de 2019 e 31 de dezembro de 2024. A análise da tendência se concentrou na série temporal, caracterizando o comportamento da taxa de detecção ao longo do período. Aplicado o método de decomposição STL (Seasonal and Trend decomposition using LOESS), separando a série em três componentes: tendência série temporal sazonalidade e ruído. Os resultados, indicaram manutenção da endemicidade, com padrão temporal estável e leve declínio no número de casos novos, evidenciando padrão epidemiológico característico de áreas hiperendêmicas, com predomínio de casos multibacilares e formas clínicas mais avançadas. A classe operacional evidencia maior prevalência da forma multibacilar (MB); os casos paucibacilares (PB), denota menor prevalência, oscilando entre 13% e 18% ao longo da série. A conclusão desse estudo é que no estado do Maranhão entre 2019 e 2024, houve redução consistente no número total de casos de hanseníase, com tendência de declínio, intercalada por leves oscilações anuais, e o total anual variou de 871 casos em 2019 para 473 casos em 2024, correspondendo a uma redução de aproximadamente 45,7%.*

*Abstract*

*Leprosy is an infectious disease caused by Mycobacterium leprae (M. leprae), persistent in several regions of the world, particularly in developing countries where poverty and low coverage of basic health and sanitation services are prevalent, as is the case in Brazil. This is an ecological, time-series epidemiological study whose objective was to analyze the trend in the leprosy detection rate in the state of Maranhão, Brazil, from 2019 to 2024. Data on new leprosy cases were obtained from the Notifiable Diseases Information System (SINAN), made available by the Ministry of Health for reported leprosy cases in Maranhão between January 1, 2019, and December 31, 2024. The trend analysis focused on the time series, characterizing the behavior of the detection rate over the period. The STL (Seasonal and Trend Decomposition using LOESS) method was applied, separating the series into three components: trend, seasonality, and noise. The results indicated continued endemicity, with a stable temporal pattern and a slight decline in the number of new cases, demonstrating an epidemiological pattern characteristic of hyperendemic areas, with a predominance of multibacillary cases and more advanced clinical forms. The operational class shows a higher prevalence of the multibacillary (MB) form; paucibacillary (PB) cases indicate a lower prevalence, ranging from 13% to 18% throughout the series. The conclusion of this study is that in the state of Maranhão between 2019 and 2024, there was a consistent reduction in the total number of leprosy cases, with a downward trend interspersed with slight annual fluctuations. The annual total varied from 871 cases in 2019 to 473 cases in 2024, corresponding to a reduction of approximately 45.7%.*

## 1 INTRODUCTION

Leprosy is an infectious disease caused by Mycobacterium leprae (M. leprae), persistent in various regions of the world, mainly in developing countries, where there is a prevalence of poverty and low coverage of basic health and sanitation services, as is the case in India, Brazil, and Indonesia. Considered one of the oldest diseases known to humankind, its origin is believed to date back to West Africa approximately 100,000 years ago, having spread globally through migratory flows, trade routes, and historical processes such as colonialism (BRAZIL, 2022).

Data from the World Health Organization (WHO) on leprosy indicate that Brazil still has a high endemic burden of the disease. In 2024, 22,129 new cases were reported, representing a 2.8% reduction compared to the 22,773 cases reported in 2023. Despite this slight decline, the country continues to rank second worldwide in absolute number of notifications. This Brazilian scenario reflects the trend observed globally: in 2024, 172,717 new cases were identified worldwide, representing a 5.5% decrease compared to 2023. These data reinforce the continuous decline of leprosy over the last decade, with a cumulative reduction of approximately 20% since 2015, showing progress, but still insufficient for the elimination of the disease as a public health problem (WHO, 2024).

Its distribution within Brazil is concentrated mainly in the Midwest, North, and Northeast regions, reflecting areas of greater social vulnerability. Given this scenario, Maranhão stood out as the state with the second highest number of new cases (2,349) in 2022, surpassed only by Mato Grosso. The detection rate was 34.67 per 100,000 inhabitants, characterizing a situation of hyperendemicity (BRAZIL, 2024).

According to the Clinical Protocol and Therapeutic Guidelines for Hansen's Disease (PCDT), a suspected case should be investigated when signs such as skin lesions with loss of sensitivity, peripheral neurological changes, or nerve thickening are present. However, confirmation can occur through clinical evaluation, laboratory tests such as smear microscopy, or molecular tests. For therapeutic purposes, cases are classified as paucibacillary (up to five lesions and negative smear microscopy) or multibacillary (more than five lesions or positive smear microscopy). Leprosy also presents in different clinical forms, which are: indeterminate, tuberculoid, dimorphic, and virchowian. Once identified, the treatment plan and patient follow-up are defined (BRASIL, 2022).

Transmission occurs mainly through prolonged contact with untreated individuals (high bacillary load), who eliminate the bacillus through the upper airways. The bacillus primarily affects the peripheral nerves and skin, but can compromise the eyes and internal organs, depending on the host's immune response. The disease can progress with varying degrees of impairment, such as functional loss and physical disabilities. Factors such as late diagnosis, male gender, high bacillary load, and the presence of leprosy reactions contribute to the risk of sequelae (BRASIL, 2022).

The expansion of primary care and leprosy control programs has led to an increase in case detection, but this does not necessarily reflect an improvement in access or quality of services, as challenges such as inadequate physical structures, a shortage of qualified professionals, and flaws in organizational processes persist. Given this context, it is essential that municipalities reinforce early diagnosis, timely treatment, surveillance, and, above all, educational actions focused on the population, as failures in the implementation of these strategies can increase social vulnerability and sustain the transmission of leprosy (Silva et al., 2023). Finally, the objective of this study was to analyze the trend in the leprosy detection rate in the state of Maranhão, Brazil, from 2019 to 2024.

## 2 METHODOLOGIES

This is an ecological time series epidemiological study whose objective was to analyze the trend in the detection rate of leprosy in the state of Maranhão, Brazil, from 2019 to 2024. The units of analysis were the time periods in years in the state of Maranhão, based on aggregate data from official health information systems. Data on new cases of

leprosy were obtained from the Notifiable Diseases Information System (SINAN), provided by the Ministry of Health.

The population estimates used as denominators for calculating the rates were extracted from the Brazilian Institute of Geography and Statistics (IBGE), considering the intercensal projections corresponding to the period analyzed. The records included all reported cases of leprosy in Maranhão between January 1, 2019, and December 31, 2024. The data were extracted in tabular format, processed, and analyzed in a statistical environment.

All notifications classified in SINAN as "new cases of leprosy" residing in the state of Maranhão and with a notification date within the period of interest (2019–2024) were included. Duplicate notifications, notifications without diagnosis date information, notifications without municipality of residence, as well as records classified as recurrence, transfer, or other types of entries that did not characterize a new case were excluded. Based on this information, leprosy detection rates were calculated, expressed per 100,000 inhabitants.

In constructing the time series, the data were aggregated by month and year of notification, resulting in a time series composed of 72 monthly observations (January 2019 to December 2024). Intermediate populations were estimated based on IBGE annual projections, using linear interpolation when necessary to obtain the monthly population. The statistical analysis evaluated the trend using the Mann–Kendall test, used to identify the presence of a monotonic trend (increasing or decreasing) over time; Sen's slope estimate, which quantifies the median variation in the rate over the period; Poisson log-linear regression modeling, considering the number of cases as the dependent variable and time (in years) as the independent variable, adjusted for the resident population (offset). The annual percentage change (APC) was calculated based on the regression coefficient. In all analyses, a significant level of 5% ($p < 0.05$) and 95% confidence intervals (95% CI) were adopted.

The trend analysis focused exclusively on the trend component of the time series, seeking to characterize the behavior of the detection rate over the period. For this purpose, the STL (Seasonal and Trend decomposition using LOESS) method was applied, which separates the series into three components: trend, seasonality, and noise. Only the trend component was considered for description and statistical inference, in accordance with the study objective. The trend component was analyzed graphically and subjected to statistical tests to verify the direction and magnitude of the temporal change. The results were presented in the form of trend graphs, annual rate tables, and annual percentage change (APC) estimates with their respective confidence intervals.

The study used secondary data in the public domain and aggregated data from SINAN and IBGE, without identifying individuals. For this reason, there was no need to submit the study to the Research Ethics Committee, in accordance with Resolution No. 510/2016 of the National Health Council, which exempts research using data in the public domain and without the possibility of identifying participants from ethical review.

## 3 RESULTS

Table 1 presents an analysis of the temporal evolution of leprosy cases in Maranhão from 20219 to 2024, indicating continued endemicity, with a stable temporal pattern and a slight decline in the number of new cases. The distribution by gender shows a consistent predominance of males throughout the period analyzed, corresponding to approximately 55% to 60% of annual cases. With regard to the race/color variable, there is a predominance of cases among brown-skinned people, followed by black and white people. The age groups reveal a higher incidence between the ages of 30 and 59, corresponding to the economically active population; the education variable shows a predominance of cases among individuals with incomplete elementary education and illiterates, which reinforces the link between leprosy and social determinants of health.

*Table 1: Statement of sociodemographic variables of the Evolution of Hansen's Disease in the State of Maranhão, from 2019 to 2024.*

| VARIABLES | YEARS | | | | | |
|---|---|---|---|---|---|---|
| | 2019 n(%) | 2020 n(%) | 2021 n(%) | 2022 n(%) | 2023 n(%) | 2024 n(%) |
| **Gender** | | | | | | |
| Male | 449 (22,97) | 296(15,14) | 300(15,35) | 287(14,85) | 341(17,44) | 282(14,42) |
| Female | 427(26,39) | 249(15,39) | 218(13,47) | 248(15,33) | 281(17,37) | 195(12,05) |
| **Race** | | | | | | |
| Unknown/White | 8(24,24) | 9(27,27) | 4(12,12) | 2(6,06) | 7(21,21) | 3(9,09) |
| White | 134(26,53) | 64(12,67) | 51(10,1) | 83(16,44) | 88(17,43) | 85(16,83) |
| Black | 141(22,24) | 88(13,88) | 112(17,67) | 92(14,51) | 123(19,4) | 78(12,3) |
| Asian | 7(38,89) | 3(16,67) | 4(22,22) | 1(5,56) | 3(16,67) | 0(0) |
| Mixed race | 584(24,81) | 380(16,01) | 344(14,5) | 356(15) | 399(16,67) | 310(13,06) |
| Native | 2(20) | 1(10) | 3(30) | 1(10) | 2(20) | 1(10) |
| **Age group** | | | | | | |
| 1 a 4 | 1(14,29) | 2(28,57) | 2(28,57) | 1(14,29) | 1(14,29) | 0(0) |
| 5 a 9 | 19(27,54) | 11(15,94) | 7(10,14) | 18(26,09) | 7(10,14) | 7(10,14) |
| 10 a 14 | 46(30,87) | 29(19,46) | 8(5,37) | 29(19,46) | 22(14,77) | 15(10,07) |
| 15 a 19 | 61(32,11) | 23(12,11) | 25(13,16) | 24(12,63) | 37(19,47) | 20(10,53) |
| 20 a29 | 123(25,95) | 80(16,88) | 58(12,24) | 77(16,24) | 76(16,03) | 60(12,66) |
| 30 a 39 | 158(26,55) | 111(18,66) | 91(15,29) | 72(12,1) | 92(15,46) | 71(11,93) |
| 40 a 49 | 165(23.74) | 103(14,82) | 107(15,4) | 92(13,24) | 125(17,99) | 103(14,82) |
| 50 a 59 | 136(22.7) | 86(14,36) | 92(15,36) | 88(14,69) | 109(18,2) | 88(14.69) |
| 60 a 69 | 118(24,58) | 61(12,71) | 72(15) | 66(13,75) | 95(19,79) | 68(14.17) |
| 70 a 79 | 36(16,29) | 25(11,31) | 42(19) | 48(21,72) | 38(17,19) | 32(14.48) |
| 80 years and more | 13(13.83) | 14(14,89) | 14(14,89) | 20(21,28) | 20(21,28) | 13(13.83) |
| **Education** | | | | | | |
| Unknown/blank | 37(14,12) | 39(14,89) | 37(14,12) | 41(15,65) | 68(25,95) | 40(15.27) |
| Illiterate | 40(24.24) | 26(15,76) | 26(15,76) | 25(15,15) | 27(16,36) | 21(12.73) |
| 1st to 4th grade incomplete | 95(27,3) | 50(14,37) | 51(14,66) | 52(14,94) | 54(15,52) | 46(13.22) |
| 4th grade complete | 34(23,78) | 25(17,48) | 24(16,78) | 18(12,59) | 26(18,18) | 16(11,19) |
| 5th to 8th grade incomplete | 140(26,72) | 65(12,4) | 99(18,89) | 79(15,08) | 85(16,22) | 56(10,69) |
| Elementary school complete | 86(27,39) | 47(14,97) | 42(13,38) | 38(12,1) | 61(19,43) | 40(12,74) |
| High school incomplete | 99(32,46) | 39(12,79) | 42(13,77) | 38(12,46) | 54(17,7) | 33(10,82) |
| High school complete | 263(22,36) | 195(16,58) | 157(13,35) | 191(16,24) | 195(16,58) | 175(14,88) |
| Higher education incomplete | 26(26,53) | 23(23,47) | 9(9,18) | 15(15,31) | 13(13,27) | 12(12,24) |
| Higher education complete | 50(22,73) | 32(14,55) | 29(13,18) | 35(15,91) | 37(16,82) | 37(16,82) |
| Not applicable | 6(33,33) | 4(22,22) | 2(11,11) | 3(16,67) | 2(11,11) | 1(5,56) |

*Table 2: Statement of clinical variables of the evolution of Hansen's disease in the state of Maranhão from 2019 to 2024.*

| VARIABLES | YEARS | | | | | |
|---|---|---|---|---|---|---|
| | 2019 n (%) | 2020 n(%) | 2021 n(%) | 2022 n (%) | 2023 n(%) | 2024 n(%) |
| **Operational Class Diagnosed** | | | | | | |
| Paucibacillary | 142(31,98) | 53(11,94) | 59(13,29) | 82(18,47) | 65(14,64) | 43(9,68) |
| Multibacillary | 734(23,46) | 492(15,72) | 459(14,67) | 453(14,48) | 557(17,8) | 434(13,87) |
| **Clinical form of notification** | | | | | | |
| Ignored/blank | 5(33,33) | 2(13,33) | 1(6,67) | 2(13,33) | 1(6,67) | 4(26,67) |
| Undetermined | 49(27,37) | 23(12,85) | 22(12,29) | 32(17,88) | 33(18,44) | 20(11,17) |
| Tuberculoid | 92(31,94) | 37(12,85) | 40(13,89) | 51(17,71) | 37(12,85) | 31(10,76) |
| Dimorphic | 537(24,19) | 373(16,8) | 312(14,05) | 331(14,91) | 381(17,16) | 286(12,88) |
| Virchowian | 149(22,68) | 79(12,02) | 110(16,74) | 88(13,39) | 127(19,33) | 104(15,83) |
| Unclassified | 44(20,56) | 31(14,49) | 33(15,42) | 31(14,49) | 43(20,09) | 32(14,95) |
| **Skin Lesions** | | | | | | |
| Reported 0 or 99 | 96(26,45) | 45(12,4) | 52(14,33) | 46(12,67) | 62(17,08) | 62(17,08) |
| Single injury | 260(29,75) | 139(15,9) | 124(14,19) | 144(16,48) | 120(13,73) | 87(9,95) |
| 2-5 injuries | 208(20,933 | 170(17,1) | 136(13,68) | 162(16,3) | 171(17,2) | 147(14,79) |
| More than 5 injuries | 12(23,25) | 191(14,23) | 206(15,35) | 183(13,64) | 269(20,04) | 181(13,49) |

Table 2 presents a temporal analysis of leprosy cases in the state of Maranhão between 2019 and 2024, according to clinical variables (operational class, clinical form, and number of skin lesions), showing an epidemiological pattern characteristic of hyperendemic areas, with a predominance of multibacillary cases and more advanced clinical forms. The operational class shows a higher prevalence of the multibacillary (MB) form. Paucibacillary (PB) cases, although present, show a lower prevalence, ranging from 13% to 18% throughout the series.

In the clinical form, there is a higher prevalence of dimorphic and Virchowian forms, which together account for more than 70% of annual notifications. The tuberculoid and indeterminate forms characterize recent infections with a lower bacillary load, maintaining lower and stable proportions.

Regarding skin lesions, the highest frequency is observed among individuals with two to five lesions and more than five lesions, confirming the predominance of multibacillary and advanced cases. This pattern remained relatively constant throughout the time series, with a slight reduction in cases with more than five lesions after 2022.

In clinical terms, there is a higher prevalence of dimorphic and Virchowian forms, which together account for more than 70% of annual notifications. Tuberculoid and indeterminate forms characterize recent infections with a lower bacillary load, maintaining lower and more stable proportions.

Regarding skin lesions, the highest frequency is observed among individuals with two to five lesions and more than five lesions, confirming the predominance of multibacillary and advanced cases. This pattern remained relatively constant throughout the time series, with a slight reduction in cases with more than five lesions after 2022.

Table 3 shows the analysis of the time series for leprosy in Maranhão from 2019 to 2024, highlighting an overall downward trend in the detection of new cases, in line with the national trend observed over the last two decades. The temporal trend of sociodemographic and clinical variables of leprosy cases in Maranhão (2019–2024) shows a significant drop in leprosy cases between 2019 and 2021, followed by stabilization between 2022 and 2024. The temporal evolution reveals patterns consistent with the epidemiological profile historically described for the disease in Maranhão.

Graph 1 The temporal trend of sociodemographic and clinical variables of leprosy cases in Maranhão (2019–2024) shows a significant decrease in leprosy cases between 2019 and 2021, followed by stabilization between 2022 and 2024. The temporal evolution reveals patterns consistent

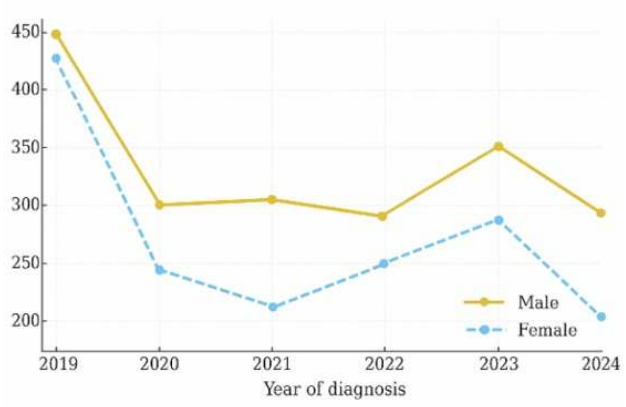
with the epidemiological profile historically described for the disease in Maranhão.

*Table 3: Overview of global trends and demographic and clinical profile of leprosy in Maranhão (2019–2024)*

| Variables | 2019 | 2024 | Δ (%) | β¹ | R² | p* | Interpretation |
|---|---|---|---|---|---|---|---|
| **Gender** | | | | | | | |
| Male | 449 | 282 | –37,2 | –33,5 | 0,355 | 0.061 | Marginal Decline (↓· |
| Female | 427 | 195 | –54,3 | –46,1 | 0,436 | 0.038 | Strong Decline (↓↓) |
| **Diagnosed Operational Class** | | | | | | | |
| Multibacillary | 734 | 434 | 40,9 | 57,7 | 0,373 | 0.047 | Significant Decline |
| Paucibacillary | 142 | 43 | –69,7 | –18,7 | 0,526 | 0.031 | Strong Decline (↓↓) |
| **Clinical Notification Form** | | | | | | | |
| Dimorphic | 537 | 286 | –46,7 | –47,2 | 0,412 | 0.055 | Significant Decline |
| Virchowian | 149 | 104 | –30,2 | –7,5 | 0,207 | 0.171 | Insignificant (-) |
| Tuberculoid | 92 | 31 | –66,3 | –12,6 | 0,598 | 0.026 | Strong Decline (↓↓ |
| Skin lesions | | | | | | | |
| >5 lesions | 312 | 181 | –42,0 | –26,1 | 0,361 | 0.069 | Marginal Decline (· |
| 2–5 lesions | 208 | 147 | –29,3 | –11,7 | 0,175 | 0.202 | Insignificant (-) |
| Single lesion | 260 | 87 | –66,5 | –34,6 | 0,504 | 0.034 | Strong Decline (↓↓ |
| Overall total | 871 | 477 | –45,2 | –50,06 | 0,409 | 0.042 | Significant Decline |

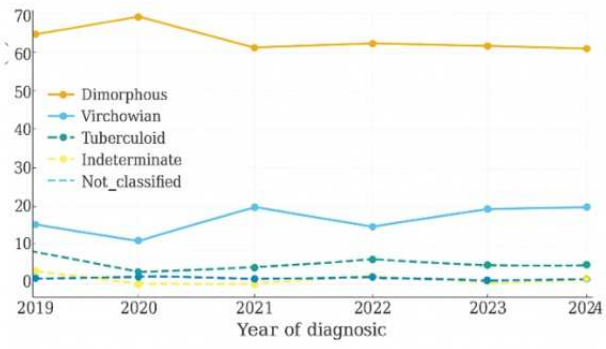
Graph 2 shows the temporal distribution of the main clinical forms of leprosy diagnosed in the state of Maranhão between 2019 and 2024, with emphasis on the dimorphic and virchowian forms, which represent the most prevalent clinical presentations and are of greatest epidemiological relevance. Throughout the period analyzed, there was a constant predominance of the dimorphic form, followed by the virchowian form, both of which accounted for most of the cases reported during the time interval.

*Chart 1: Overall temporal distribution of leprosy cases in the state of Maranhão by gender.*




Graph 3 shows the temporal evolution of multibacillary and paucibacillary clinical forms of leprosy in the state of Maranhão between 2019 and 2024, based on official notification records from the Notifiable Diseases Information System (SINAN). The analysis of the distribution highlights the dynamics of transmission, the epidemiological profile, and the effectiveness of the control strategies implemented during the period.

*Chart 2: Trend in dimorphic and Virchowian clinical forms*




Graph 4 shows the temporal evolution of the proportion of cases of multibacillary (MB) and paucibacillary (PB) clinical forms of leprosy registered in the state of Maranhão between 2019 and 2024. Analysis of the proportion between these forms is an essential epidemiological indicator for assessing the behavior of the endemic disease, the effectiveness of early diagnosis, and the performance of surveillance actions within the scope of Primary Health Care (PHC).

*Chart 3: Analysis of the number of multibacillary and paucibacillary cases*

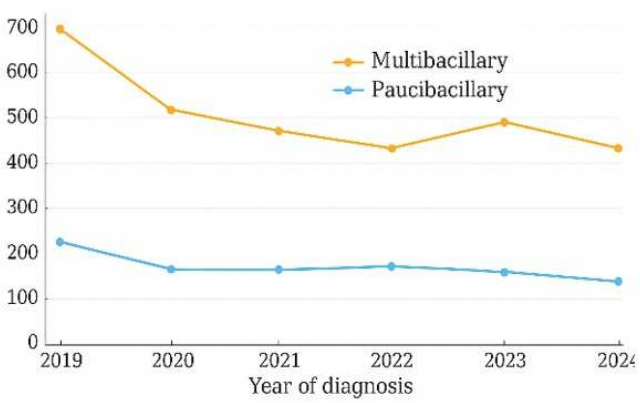
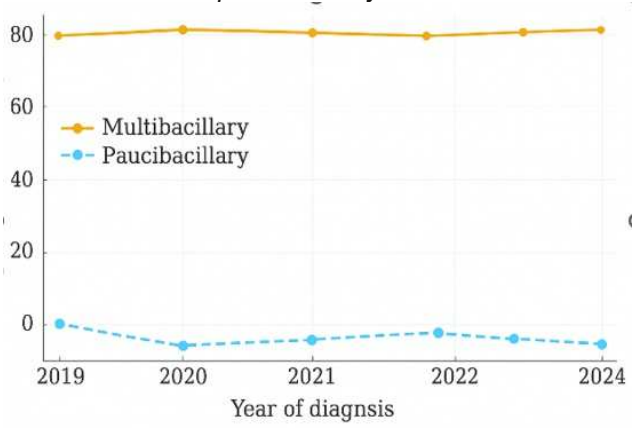


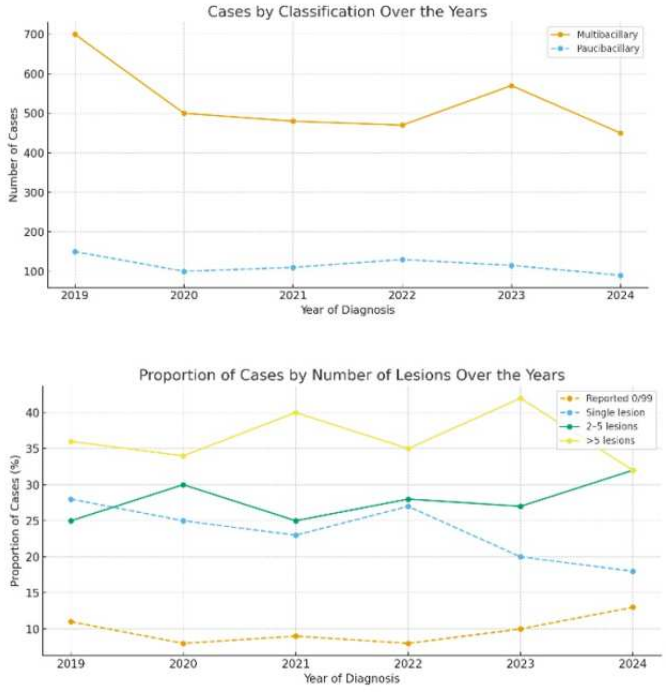

*Chart 4: Analysis of the proportion of multibacillary and paucibacillary cases*



Graph 5 shows the predominant proportion of multibacillary (MB) cases among reported leprosy cases in the state of Maranhão from 2019 to 2024. The predominance of this clinical form, compared to paucibacillary (PB) forms, is a critical indicator of the epidemiological behavior of the disease, reflecting the intensity of transmission, the effectiveness of early diagnosis, and the quality of surveillance and control actions carried out within the healthcare network.

Graph 6 shows the temporal distribution of skin lesions in individuals diagnosed with leprosy in the state of Maranhão from 2019 to 2024. The variable “number of lesions” is an essential clinical-epidemiological marker for the operational classification of the disease and for the assessment of the bacillary load, since the extent of the lesions is directly associated with the clinical form and transmissibility of Mycobacterium leprae.

*Chart 5: Analysis of the hegemonic proportion of the multibacillary form (A) and analysis of the distribution of skin lesions between 2019 and 2024 (B)*




## 4 DISCUSSION

In the state of Maranhão between 2019 and 2024, there was a consistent reduction in the total number of leprosy cases, with a downward trend interspersed with slight annual fluctuations. The annual total ranged from 871 cases in 2019 to 473 cases in 2024, corresponding to a reduction of approximately 45.7%. This downward trajectory is accompanied by a slight biennial fluctuation, with signs of recovery in 2023 after the impact of the pandemic on notifications between 2020 and 2021. The decomposition of the time series revealed three distinct components, the first with a linear downward trend; the second with weak seasonality with an approximate periodicity of two years; the third with an irregular component (residual) of low amplitude, indicating stability of the additive model (Brazil, 2025).

In the analysis stratified by gender, there was a predominance of males, maintaining an average proportion of 56% of total cases, with both curves (male and female) showing parallel behavior, reinforcing that temporal fluctuations reflect population and institutional factors, rather than gender differences. The study by Castro and Ribeiro (2023) in different states in the northeast observed that in the 15-19 age group, positive cases of leprosy predominated among males, representing 72.7% of cases, also emphasizing that both sexes were subject to contamination, but that females represented a lower number of cases because they were the sex that most sought preventive public health services.

With regard to the race/color variable, there is a predominance of cases among brown-skinned people, followed by black and white people. This distribution reflects the demographic composition of the state, but also expresses social and racial inequalities in access to health services and vulnerability to living conditions that favor the maintenance of transmission. The relative stability among racial groups over the years, without significant fluctuations, suggests the absence of marked cycles and reinforces the constancy of the observed distributional pattern. The research by (Oliveira et al., 2020) states that the flexibility of color classification in Brazil makes it difficult to differentiate between the two groups, as well as the proximity in terms of socioeconomic indicators between the two groups, and considers black and brown people together as a single category (Oliveira et al., 2020).

Analysis by age group reveals a higher incidence among people aged 30 to 59,

corresponding to the economically active population, which has a direct impact on productivity and social costs resulting from work disability. The presence of cases in the 10-19 age group indicates continued transmission and recent infection, highlighting failures in interrupting the chain of contagion and the need to intensify epidemiological surveillance in schoolchildren. The evolution of this variable over the time series shows attenuated cyclical behavior, with biennial fluctuations possibly related to active detection actions in certain periods. A similar study by Maria Rosa Gonçalves Nunes and Beatriz Santana de Souza Lima (20219) comments that these results are indicators of the endemicity of the region, where the emergence of new cases in children characterizes important epidemiological data, as it confirms the precocity of exposure and the persistence of the disease, functioning as an indicator of endemicity.

Regarding education, there is a predominance of cases among individuals with incomplete elementary school education and illiterate individuals, which reinforces the link between leprosy and social determinants of health. Higher levels of education show a lower frequency of cases, suggesting that education positively influences knowledge about early signs and access to diagnosis. This relationship is widely documented in the literature, which highlights low educational attainment as a risk factor for late diagnosis and disabling sequelae. The study by Brito and Nascimento (2021) analyzes the relationship between social determinants and late diagnosis of leprosy in Brazil. The findings show that factors such as low educational attainment, social vulnerability, stigma, and lack of professional training contribute to late diagnosis, which results in worsening of the disease and increased degrees of physical disability. (Brito; Nascimento, 2021).

The analysis of the distribution of clinical forms of leprosy in Maranhão between 2019 and 2024 showed a consistent predominance of the dimorphic form, followed by the virchowian and tuberculoid forms, indicating a clinical pattern associated with continued transmission and late detection of cases. Throughout the period analyzed, the dimorphic form accounted for approximately 60% to 65% of annual notifications, showing a slight decline from 2021 with a recovery in 2023. The Virchowiana form was associated with the most severe cases and the highest infectious potential, representing 15% to 22% of cases, with fluctuations reflecting the resumption of surveillance activities after the impact of the COVID-19 pandemic. The study by Silva et al. (2021), conducted in the context of the COVID-19 pandemic, a period of significant changes in the global and regional health surveillance landscape, analyzes that the suspension of most activities related to NTDs resulted in delays in diagnosis, treatment, morbidity management, and disability prevention, with a significant reduction in the detection of new cases of leprosy, considering only the years of the pandemic, at the national level (Silva et al., 2021).

In the present study, tuberculoid and indeterminate forms occurred in low proportions (less than 10%), reflecting a still limited number of early diagnoses. The temporal decomposition of the Dimorphic form series revealed a gradual downward trend, slight seasonal variation every two years, and low amplitude residuals, indicating model stability. These findings suggest that the reduction in the absolute number of cases was accompanied by a maintenance of the structure of multibacillary form predominance.

The percentage analysis reinforces this trend, indicating that even with interannual variations, the dimorphic and Virchowian forms together account for about 80% of reported cases. This clinical configuration points to an epidemiological profile of late detection, requiring intensification of early diagnosis strategies, training of primary care teams, and active surveillance in endemic areas. In Sousa's (2025) study, the dimorphic form was the most frequent among confirmed cases, followed by the Virchowian form, both of which are multibacillary forms associated with a higher infectious load and, consequently, a greater potential for disease transmission. In the same study, they report that the significant presence of indeterminate and tuberculoid forms suggests that some cases are still being

identified in the early stages.

The analysis of the paucibacillary and multibacillary operational class diagnosis showed that, between 2019 and 2024, leprosy in Maranhão presented a consistent predominance of multibacillary (MB) cases over paucibacillary (PB) cases, reflecting an epidemiological pattern characteristic of active transmission and late diagnosis. In the period analyzed, the number of multibacillary cases decreased from 734 in 2019 to 434 in 2024, while paucibacillary cases fluctuated between 53 and 142 cases, maintaining an average proportion of 86% MB and 14% PB. This difference indicates that most individuals were diagnosed in advanced stages of the disease, with a high bacillary load and greater potential for community transmission. A similar study was conducted by Souza et al. (2022), where the proportion of paucibacillary cases showed a downward trend, however, it showed an increasing trend in the proportion of new multibacillary cases, and this increase may indicate ineffective and/or late diagnosis of the disease (Souza et al., 2022).

The temporal behavior revealed a general downward trend in notifications of both classes (paucibacillary and multibacillary) from 2020 onwards, accompanied by a slight recovery in 2023, possibly associated with the resumption of post-pandemic surveillance services. The decomposition of the time series showed that the downward trend is the main explanatory component of the annual variation, while seasonality showed low amplitude, suggesting that the observed fluctuations are more related to the operational dynamics of the services than to environmental or demographic factors. In the study by LDS Sanches · 2023 of reported cases of leprosy in the elderly, the multibacillary operational classification (75%) had a higher frequency of cases than the paucibacillary classification (25%), since epidemiological data indicated that the most common operational classification was multibacillary.

The proportional analysis reinforces the hegemony of the multibacillary form throughout the entire period, with no signs of reversal or significant reduction, pointing out that this constancy poses persistent challenges in detection and access to early diagnosis, especially in the most vulnerable regions. For Borges PKO, Martins CM, Stocco C, 2024, the effects of the recovery of health services after the reduction of morbidity and mortality due to COVID-19 and the end of the emergency in the early years of the pandemic depend on the flexibility and resilience of surveillance systems and health services Borges PKO, Martins CM, Stocco C, 2024.

Analysis of the distribution of skin lesions between 2019 and 2024 revealed a trend toward a predominance of cases with multiple lesions, suggesting late diagnosis and more advanced clinical forms of leprosy in Maranhão. The categories with two to five lesions and more than five lesions accounted for most of the notifications, corresponding to about 60% to 70% of annual cases. In 2019, the group of patients with more than five lesions represented 36% of cases, a figure that fluctuated over time, reaching approximately 38% in 2023 and 32% in 2024, which reinforces the persistence of cases in more severe stages of the disease.

The categories of single lesion and 0/99 (no information) remained lower, ranging from 15% to 25%, which highlights the underreporting of initial cases and possible gaps in clinical records. Also in the study by LDS Sanches · 2023, the majority of leprosy cases in the elderly presented more than five (5) skin lesions. In 1982, the World Health Organization (WHO) proposed a simplified and operational classification based on the number of skin lesions. This system organizes patients into two groups, as cases with up to five lesions are considered paucibacillary (PB) and those with more than five lesions are identified as multibacillary.

Analysis of the time series for leprosy in Maranhão from 2019 to 2024 shows an overall downward trend in the detection of new cases, and the total reduction of approximately 45% indicates relative progress in control, although the pattern of decline shows annual variation possibly associated with operational fluctuations, the COVID-19 pandemic, and the episodic intensification of surveillance actions (Ramos et al., 2022).

The analysis stratified by sex revealed a

more pronounced decline among women (–54%) than among men (–37%), which may reflect differences in access to health services or exposure to risk factors, as pointed out in national studies on gender inequality in leprosy (Santos et al., 2025). The persistent predominance of multibacillary cases, albeit with a 41% reduction, confirms late diagnosis as a central component in the dynamics of transmission, as reported by Lima et al. (2020).

Among the clinical forms, dimorphic remained predominant (≈ 60%), followed by virchowian, with a percentage reduction of less than 35%. The predominance of multibacillary forms indicates continuity in the detection of cases in advanced stages, a scenario also described in national studies (Souza et al., 2020). In the clinical severity variables, it was observed that the categories with multiple skin lesions (2–5 and > 5) concentrated the highest proportion of cases, supporting the hypothesis of delayed diagnosis and maintenance of active sources of infection (De Souza et al., 2020).

Linear regression by grouped series showed negative angular coefficients and significant p-values ($p < 0.05$) for most variables, confirming a statistically robust downward trend. However, moderate $R^2$ values (0.3–0.6) suggest additional influence of external factors on detection, such as reorganization of surveillance flows and variability in population coverage. Thus, despite progress, the findings indicate that the elimination of leprosy as a public health problem still depends on the intensification of active search strategies, early diagnosis, and community health education.

The decomposition of the total time series showed an overall downward trend in the absolute number of cases with skin lesions, with low amplitude seasonality and stable residuals, reinforcing that the observed fluctuations are due to operational factors and not structural changes in the epidemiological profile.

The proportional analysis indicated a predominance of categories with multiple lesions, reflecting the persistence of late diagnoses and active transmission in the community.

## 5 CONCLUSION

These results reinforce the importance of intensifying early detection actions, clinical training, and strengthening active surveillance, especially in regions with higher incidence and social vulnerability. In terms of public policy, the findings highlight the need to intensify active search actions, train primary care teams, and implement active surveillance strategies to interrupt the chain of transmission and reduce the multibacillary burden in the state.

This study has limitations due to the use of secondary data from information systems, which may present inconsistencies in the quantity, quality, and processing of their information and are subject to change. This is relevant data, since each geographic area depends on its own technical and operational conditions of the epidemiological surveillance system to identify, report, investigate, and confirm cases of leprosy.

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