Revista Prevenção de Infecção e Saúde
The Official Journal of the Human Exposome and Infectious Diseases Network

ORIGINAL ARTICLE

DOI: 10.26694/repis.v11i1.6316

Assessment of epidemiological and spatial factors associated with physical disabilities due to leprosy at the end of treatment

Avaliação dos fatores epidemiológicos e espaciais associados às incapacidades físicas da hanseníase ao término do tratamento

Evaluación de los factores epidemiológicos y espaciales asociados a las discapacidades físicas por lepra al final del tratamiento

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How to cite this article:
Oliveira NG, Batista LC, Costa RM, Cortela DCB, Cavalcante RS, Baptista IMFD. Assessment of epidemiological and spatial factors associated with physical disabilities due to leprosy at the end of treatment. Rev Pre Infec e Saúde [Internet]. 2025; 11:01: 6316. Available from: http://periodicos.ufpi.br/index.php/repis/article/view/6316. DOI: https://doi.org/10.26694/repis.v11i1.6316.

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ABSTRACT

Introduction: Identifying clinical, epidemiological, and operational factors associated with the development of physical disabilities after leprosy treatment is essential to improve prevention and care strategies, reduce the socioeconomic impact of the disease, and improve the quality of life of affected individuals. Objective: To evaluate the factors associated with the presence of physical disabilities at the end of treatment in a hyperendemic setting. Methodology: A retrospective study was conducted with 495 leprosy patients residing in Cáceres, Mato Grosso (MT), using data obtained from the Regional Health Office. Epidemiological, clinical, and geospatial variables were analyzed. Data analysis was performed using logistic regression, considering a p-value < 0.05 as significant. An analysis of the spatial flow between the patients' place of residence and the health services responsible for notification was also performed. Results: Among the 247 records with complete data, the independent factors associated with physical disabilities at the end of treatment were: age (odds ratio [OR], 1.04 [1.02–1.08]; p<0.01), multibacillary operational classification (OR, 2.69 [1.08–6.71]; p=0.03), and presence of physical disabilities at diagnosis (OR, 5.10 [2.07–12.55]; p<0.01). In the geospatial analysis, a centralization of care was observed in a referral service, with an average patient travel distance of 2.09 km. This service concentrated 76.5% of the notifications; the remaining 23.5% were notified by primary health care. Conclusions: The findings suggest late detection and highlight the need to strengthen primary health care for early diagnosis and systematic follow-up of physical disabilities, starting at the time of diagnosis, in order to reduce the rates of physical disabilities at the end of treatment.

DESCRIPTORS

Brazil. Geographic Information System. Health services. Leprosy. Physical disabilities.

Submitted: 09/12/2024
Accepted: 03/10/2025
Published: 29/10/2025

INTRODUCTION

Leprosy is a chronic infectious disease caused by Mycobacterium leprae and Mycobacterium lepromatosis[1-3]. Both primarily affect peripheral nerves, triggering a granulomatous response that results in neural damage and, consequently, the development of physical disabilities (PD)[4,5]. The World Health Organization (WHO) classifies physical disabilities into three grades: grade 0, no disability; grade 1, loss of sensation in the hands or feet; and grade 2, visible disability. The latter is considered an epidemiological indicator of late diagnosis[6].

Physical disabilities compromises patients' daily activities, reduces work capacity, restricts social participation, and intensifies stigma and discrimination. These factors directly impact the disease burden and exacerbate socioeconomic problems in endemic regions. For this reason, leprosy remains a significant Neglected Tropical Disease, especially in developing countries, where it constitutes a major public health problem[7,8].

In this context, the WHO launched the Global Leprosy Strategy 2021–2030, which has "zero disability" as one of its main goals. This proposal reflects recent epidemiological changes and emphasizes the need for actions aimed at early diagnosis, reducing the proportion of new grade 2 cases, and strengthening access to health services, including promoting the mental well-being of those affected[9].

In Brazil, the Ministry of Health has adopted strategies aimed at reducing and managing physical disabilities, prioritizing early detection, prevention, and treatment, in addition to strengthening the surveillance system. National actions also seek to adapt interventions to regional specificities, given the heterogeneity of the endemic disease within Brazil[10].

Treatment is provided with standardized multidrug therapy (MDT-U), provided by Basic Health Units (BHU)[11], which are the main entry point for the Unified Health System (SUS)[12]. Supervised administration of doses allows for continuous assessment of the presence of PD throughout treatment. Patients who arrive with physical disabilities or who develop it during treatment should be offered rehabilitation measures, curative interventions, and self-care guidance[11].

However, disease control in Brazil remains challenging. According to the WHO, in 2023, the country reported 22,773 new cases of leprosy, placing it among the three countries that showed an increase in detection compared to the previous year: Brazil, with a 16% increase, Indonesia 15.6%, and India 3.9%[13]. Although the country's endemicity parameter increased from "high" to "medium" in 2020, the state of Mato Grosso maintained the highest detection rate of new cases (66.20/100,000 population) and presented significant PD indicators[14-16], with many patients already presenting to healthcare services with physical disabilities. Nationally, the state of Mato Grosso recorded 291 new cases of Grade 2 physical disabilities reported in 2023[14].

In 2023, among the 45 reported cases, 8 (17.8%) already presented a grade 2 physical disability at the time of diagnosis, a value classified as high (≥10.0%), according to the parameters of the Ministry of Health. It was observed that 10 (22.2%) cases were not evaluated for the presence of physical disabilities at diagnosis, which corresponds to a proportion of evaluation considered precarious (<75.0%). At the end of treatment, only 14 (31.1%) cases were evaluated for physical disabilities, of which 8 (57.1%) remained with some degree of disability (17,18). Considering this scenario, this study aims to evaluate the factors associated with the presence of physical disability at the end of treatment in a hyperendemic context.

METHODS

Study Design and Data Source

A retrospective study was conducted using the database of the Regional Health Office of Cáceres, Mato Grosso, which included sociodemographic, clinical, and operational information from health services regarding patients reported with leprosy from 2008 to 2018. The following variables were selected: sex, age, and race, dates of diagnosis and discharge, operational classification (multibacillary - MB or paucibacillary - PB), type of treatment, reactive episodes (type 1 or 2), grade of physical disabilities at diagnosis and discharge, address, and reporting unit. The data were organized and subjected to statistical and geospatial analyses.

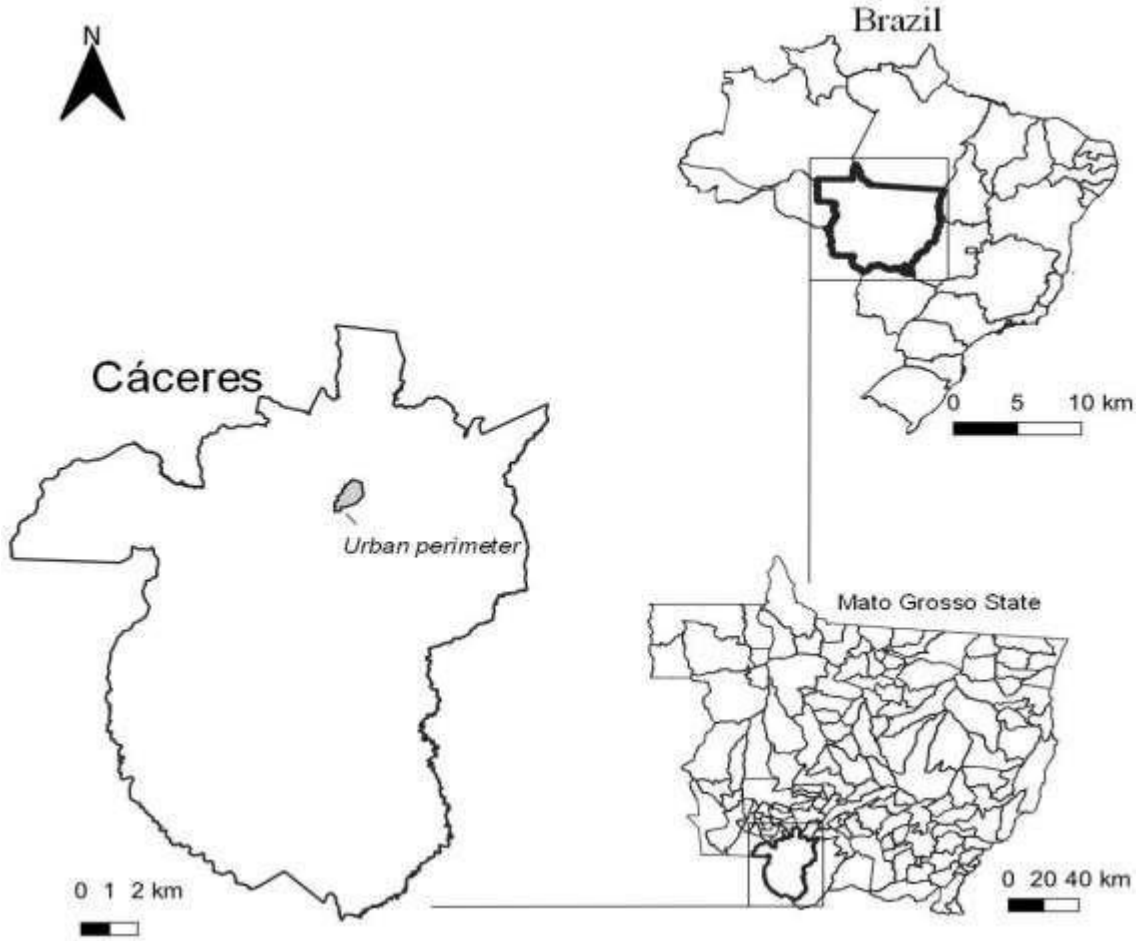
Study Area

Cáceres is located in the state of Mato Grosso (MT), covering a territorial area of 24,398 km², although it has a relatively small urban perimeter (Figure 1). According to the 2010 Demographic Census, its population was estimated at 87,942 inhabitants.

During the study period, the municipality had a Dermatology and Danitary Pulmonology Outpatient Clinic (DSPO), which served as a regional referral center for leprosy, leishmaniasis, and tuberculosis. In the case of leprosy, the DSPO was responsible for addressing clinical complications, adverse reactions to treatment, episodes of reactive reactions, and relapses, in addition to offering differential diagnosis and promoting training for primary health care professionals[11].

The primary care network consisted of 11 BHUs, all linked to the Family Health Program. Each unit had a multidisciplinary team consisting of a physician, nurse, nursing technician, and four to six full-time community health agents. The teams were organized geographically, covering areas of up to 1,000 households without overlap or gaps between their coverage areas[12].

Figure 1. Location of the urban perimeter of Cáceres, Mato Grosso.



Source: Prepared by the authors. 2025.

Statistical Analysis

Categorical variables were presented as absolute and relative frequencies, while continuous variables were described as median, first, and third quartiles. The chi-square test or Fisher's exact test were used to analyze categorical variables; for continuous variables, the Mann-Whitney U test, and the McNemar test for categorical dependent variables. Leprosy treatment differed only between the PB and MB forms, depending on the medications used and the duration of treatment, generating high collinearity between the therapeutic regimen and the operational classification. For this reason, the treatment

regimen was not included in the model. Instead, the variable "complete treatment" was considered, defined as the full use of prescribed doses, due to its influence on the clinical outcome. Although the dependent variable (physical disabilities grades: 0, 1, and 2) was ordinal, it was decided not to use multinomial logistic regression because some independent variables presented very low values, which would significantly compromise the quality of the model. Therefore, the dependent variable was treated as dichotomous (presence or absence of physical disabilities at the end of treatment), and logistic regression was applied to construct the adjusted model.

Variables with p-values less than 0.1 in the univariate analysis were included in the multivariate analysis. The adjusted model was developed by logistic regression using the input method to insert variables into the model. The goodness-of-fit was verified by the Hosmer-Lemeshow test, whose p-value was 0.557, indicating no significant differences between the predicted and observed values. Therefore, the final model presented good quality. In the final model, p-values <0.05 were considered statistically significant. Statistical analyses were performed using SPSS version 23.0 (IBM, USA) and Epi Info™ version 7.2.2.6 (Centers for Disease Control and Prevention – CDC, USA).

Spatial Analyses

To investigate the movement of patients with physical disabilities to healthcare services, a flow analysis was performed between their homes and the facilities where they were treated. The variables used were: detection mode, physical disabilities grade at discharge, and the addresses of the patients and the healthcare facilities responsible for their care.

Flow analysis was chosen because it allows for the identification of anomalies or specific patterns in movement, such as the concentration of notifications in specific health units and potential gaps in diagnosis[20-22]. Each line represented a patient's trajectory, color-coded according to the mode of entry into the health service: blue, cases detected through spontaneous demand; red, cases referred; and yellow, cases identified through household and social contact testing. The coverage areas of the BHUs were recreated from maps provided by the Municipal Health Department and overlaid on patient movement flows, allowing for the assessment of the proportion of cases captured by each unit.

The shapefiles with the boundaries of the municipality of Cáceres were obtained from the Brazilian Institute of Geography and Statistics (IBGE)[18]. The addresses of the patients, BHU and DSPO were transformed into geographic coordinates in the format of degrees, minutes and seconds (DDD° MM' SS. S") in Google Earth Pro 7.3.2 and imported into the Quantum GIS 3.14 software. The data were analyzed in the SIRGAS 2000 Geographic Coordinates system. All the information generated was organized in a Microsoft® Excel spreadsheet and submitted to Epi Info™ for descriptive statistics.

Physical Aspects

The study was approved by the Research and Ethics Committee of the Lauro de Souza Lima Institute, under opinion number 3.419.641, meeting national ethical standards for research involving human beings.

RESULTS

Between 2008 and 2018, 495 cases of leprosy were reported. However, only 247 (49.9%) had the degree of physical disabilities recorded at the beginning and end of treatment, thus constituting the study population.

The mean age of the patients was 47 years (34–56), with a predominance of males (57.9%) and self-identified brown skin color (55.1%), characteristics similar to those observed in the other 248 patients diagnosed during the same period. However, the 247 patients included had a lower level of education, with 64.6% having less than eight years of schooling (incomplete elementary or high school). Furthermore, a lower proportion of cases in the multibacillary (MB) form was observed compared to the group excluded from the analysis (46.6% vs. 62.1%; p<0.01) (Table 1).

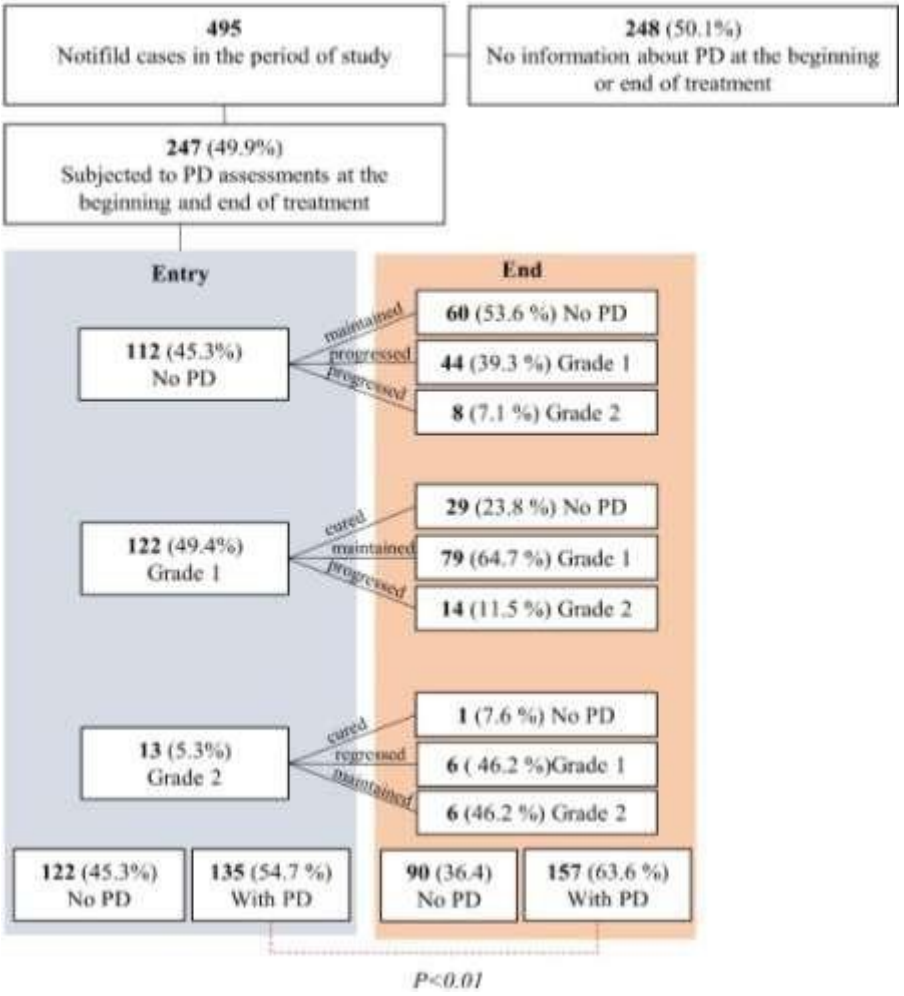
Table 1. Clinical and epidemiological characteristics of the 495 patients with leprosy diagnosed between 2008 and 2018, in the municipality of Cáceres (MT), according to information on physical disabilities.

	Patients without physical disabilities **information N=248**	**Patients with** physical disabilities **information (study population) N=247**	***p-value***
Age (years)	45.0 [32.0 – 57.0]	47.0 [34.0 – 56.0]	0.68
Male	151 (60.9)	143 (57.9)	0.49
Rural residence	39 (15.7)	52 (21.1)	0.32
Skin color			0.61
White	75 (30.2)	66 (26.7)	
Black	32 (12.9)	41 (16.6)	
Brown	138 (55.6)	136 (55.1)	
Other	02 (0.8)	04 (1.6)	
Education (years)			0.10
0	33 (15.5)	22 (9.6)	
1–8	115 (54.0) [b]	148 (64.6) [a]	
9–11	44 (20.7)	41 (17.9)	
≥12	21 (9.9)	18 (7.9)	
Operational classification			<0.01
Multibacillary	154 (62.1)	115 (46.6)	

Legend: Different letters indicate statistical difference, where a > b ($p<0.05$).
Source: Prepared by the authors, 2025.

As shown in Figure 2, at the time of admission, 135 patients (54.7%) had some degree of physical disabilities, of which 122 (49.4%) had grade 1 and 13 (5.3%) had grade 2. At the end of treatment, 157 patients (63.6%) had grade 1 and 28 (11.3%) had grade 2. There was a significant increase in the overall prevalence of physical disabilities at the end of treatment (54.7% vs. 63.6%; $p<0.01$). Furthermore, 63.4% of individuals showed PD progression, while only 22.0% were cured. The prevalence of physical disabilities at the end of treatment was higher among patients treated at DSPO compared to those treated at BHU (68.8% vs. 43.4%; $p<0.01$).

Figura 2. Flowchart of data selection evaluated in the study and progression of physical disabilities. Absence of PD is equivalent to Grade 0.



Source: Prepared by the authors, 2025.

Factors associated with the development of physical disabilities at the end of treatment were assessed by univariate and multivariate analyses (Table 2). Treatment adherence was high in both groups, with 96.2% of patients who developed physical disabilities receiving their full doses and 94.4% of those who did not, with no significant difference. For each additional year of life, the chance of developing some degree of physical disabilities increased by 4% (odds ratio [OR], 1.04 [1.02–1.08]; p<0.01). Patients with MB leprosy were 2.7 times more likely to develop physical disabilities (OR, 2.69 [1.08–6.71]; p=0.03). The presence of physical disabilities at diagnosis increased the chance of physical disabilities at the end of treatment by 5.1 times (OR, 5.10 [2.07–12.55]; p<0.01).

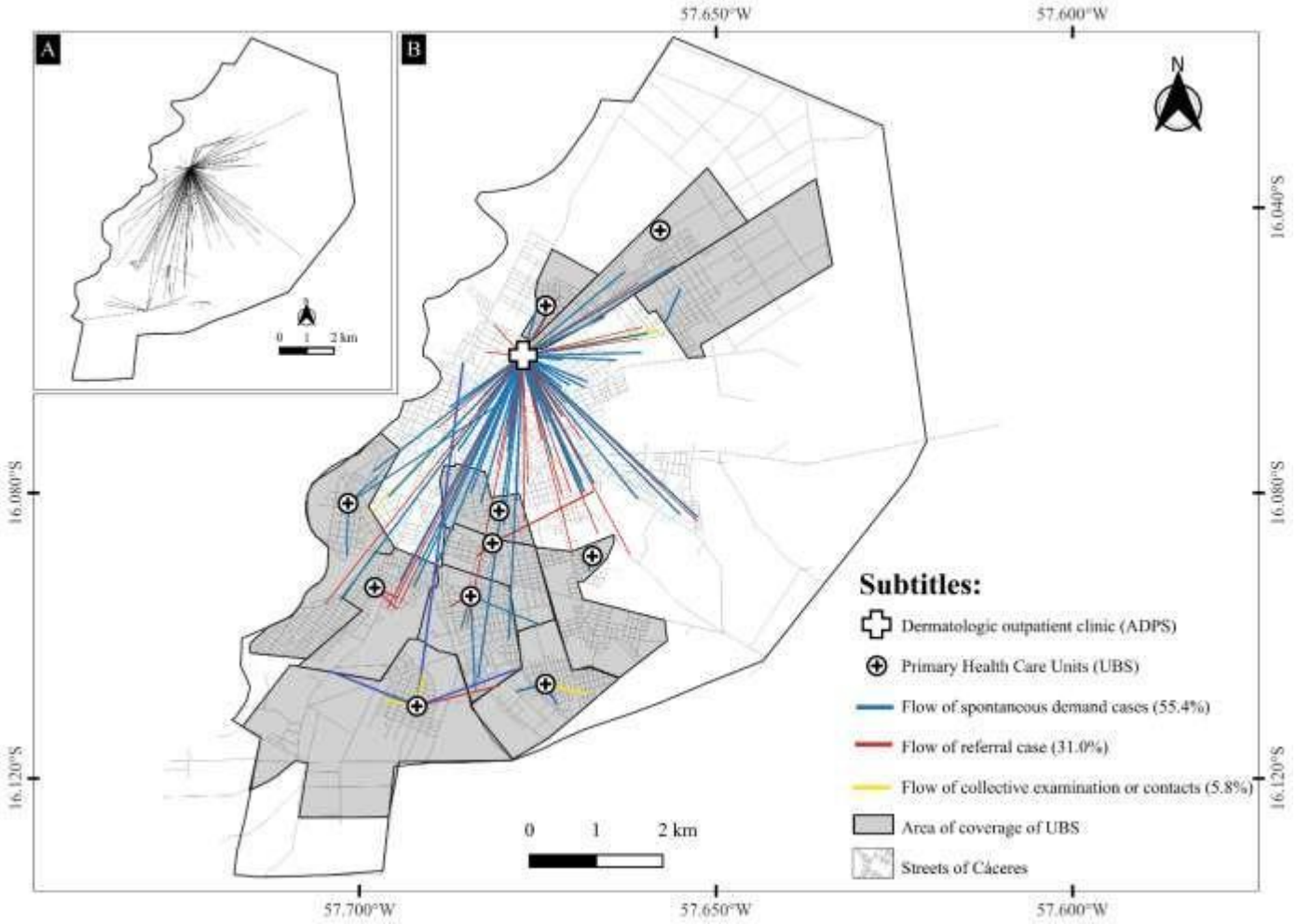
Table 2. Factors associated with the development of leprosy-related physical disabilities at the end of treatment in 247 patients in the city of Cáceres.

		Univariate analysis			Multivariate analysis	
	Without PD (n=90)	PD (n=157)	OR (95% CI)	*p-value*	OR (95% CI)	*p-value*
Age (years)	37 [29 – 51]	51 [39 – 58]	...	<0.01	1.04 (1.02 – 1.08)	<0.01
Male	47 (52.2)	96 (61.1)	1.44 (0.85 – 2.43)	0.17	...	
Rural residence	15 (16.7)	37 (23.6)	1.54 (0.79 – 3.00)	0.20	...	
Color				0.86		
White (reference)	23 (25.6)	43 (27.4)	...		...	
Black	17 (18.9)	24 (15.3)	0.75 (0.33 – 1.68)	0.49	...	
Brown	49 (54.4)	87 (55.4)	0.95 (0.51 – 1.75)	0.86	...	
Other	01 (1.1)	03 (1.9)	1.60 (0.15 – 16.31)	0.68	...	
Education (years)				**<0.01**		
0 (reference)	06 (6.7)	16 (10.2)	...		...	
1–8	44 (48.9)	104 (66.2)	0.88 (0.32 – 2.41)	0.81	3.97 (0.69 – 22.76)	0.12
9–11	21 (23.3)	20 (12.7)	0.35 (0.11 – 1.09)	0.07	2.38 (0.32 – 17.64)	0.39
≥12	13 (14.4)	05 (3.2)	0.14 (0.03 – 0.58)	<0.01	3.21 (0.30 – 34.30)	0.33
Operational classification						
Multibacillary	29 (32.2)	86 (54.8)	2.54 (1.48 – 4.38)	<0.01	2.69 (1.08 – 6.71)	0.03
BI	30 (39.0)	52 (39.4)	0.98 (0.55 – 1.74)	0.95	...	
PD in diagnosis	30 (33.3)	105 (66.9)	4.03 (2.33 – 7.00)	<0.01	5.10 (2.07 – 12.55)	<0.01
Complete treatment	85 (94.4)	150 (96.2)	0.68 (0.20 – 2.29)	0.53	...	
Reaction episode	63 (87.5)	82 (73.2)	0.39 (0.17 – 0.88)	0.02	1.57 (0.46 – 5.30)	0.46

Legend: 95% CI, 95% confidence interval; OR, odds ratio; PD = physical disabilities; BI = positive bacilloscopic index.
Source: Prepared by the authors, 2025.

In the spatial analysis, among the 247 patients with complete physical disabilities information, it was possible to accurately geo-reference 189 cases (76.5%), of which the majority (147 – 77.7%) were treated by the DSPO (Figure 3A). The spatial flows of cases with physical disabilities at the end of treatment revealed nine distinct trajectories: the main one concentrated 76.5% of the patients notified by the DSPO, while the remaining eight flows corresponded to 23.5% of the patients notified by the BHU (Figure 3B). Regarding the detection mode, the majority of cases (55.4%) were admitted by spontaneous demand, and 31.0% resulted from referrals from the BHU to the DSPO. A smaller flow (5.8%) was also observed, detected by mass testing or contact tracing. The analysis of BHU coverage showed that 71.1% of geo-referenced patients lived in areas not covered by these units. Among those living in covered areas, 40.3% were notified by the DSPO, reinforcing its centrality in care. The mean distance traveled by patients was 2.09 km for those served by the DSPO and 999.7 meters for those served by BHU, also recording the longest distance traveled by a patient served by the DSPO (5.37 km).

Figure 3. (A) Flowchart of the 189 patients with complete information on leprosy-related physical disability. (B) Flowchart of 119 patients with leprosy-related physical disability, according to the mode of detection at the reporting health facility. Excluding the flowchart recorded as Other or Not Reported, these cases represented 7.8% of the total.



Source: Prepared by the authors, 2025.

DISCUSSION

This study demonstrated that the burden of leprosy remains extremely high in the Central-West region of Brazil, with a predominance of severe forms of the disease. A high proportion of physical disabilities at the time of diagnosis (54.7%) was found, a value significantly higher than that reported by a large Brazilian cohort, which included a physical disabilities rate of 27% at the time of diagnosis. This difference can be partially explained by the nationwide scope of the cohort, which included areas with varying levels of endemicity and unequal access to health services, contrasting with the profile of Cáceres, a hyperendemic municipality.

Cáceres presented a worrying scenario, with more than half of the patients presenting some degree of physical disabilities at diagnosis, a classic indicator of late detection and a marker of the health system's fragility in adequately managing this population. physical disabilities worsens the course of the disease, requiring prolonged monitoring, greater attention to rehabilitation, and hindering patients' mobility and access to services.

Analysis of the sociodemographic profile showed that 64.6% of patients had a low level of education, of which 54% had some degree of physical disabilities at diagnosis. This finding suggests that individuals with less education are more exposed to late diagnosis, either due to difficulty accessing the healthcare system or due to a lower ability to recognize the early signs of leprosy. A similar result was observed in a cross-sectional cohort study conducted in Northeast Brazil, where low education was associated with

delayed diagnosis of the disease, even after adjusting for demographic and clinical variables[22]. This evidence reinforces the importance of continuing health education strategies targeted at low-education populations, in order to reduce barriers to accessing care and preventing physical disabilities.

Among the factors associated with the development of physical disabilities at the end of treatment, advanced age, operational classification MB, and the presence of physical disabilities at the time of diagnosis stood out. With each year of age, the risk of physical disabilities increased by 4%, a result that is consistent with the findings of Raposo et al. (2018)[23] and Smith et al. (2014)[24] who also observed a higher risk in older patients.

This pattern is due to the progressive and chronic nature of leprosy; therefore, the older the age at diagnosis, the greater the risk of developing physical disabilities. Therefore, early diagnosis and treatment are important strategies, especially in young age groups, as they contribute to preventing the progression of severe forms.

MB patients had an almost three times higher risk of developing physical disabilities at the end of treatment. In particular, the dimorphic and Virchowian clinical forms, which have a higher bacillary load and are associated with a higher frequency of reactive episodes, increase the risk of neuropathies and physical disabilities[25]. However, this study was unable to assess the influence of reactive episodes due to the lack of records in the database.

Furthermore, the presence of physical disabilities at diagnosis was a factor with the greatest impact, increasing the chance of developing maintenance or progression by more than fivefold at the end of treatment. Although treatment adherence was high (>90%), only 22.3% of patients with physical disabilities at diagnosis were cured of physical disabilities.

Another concern is the high progression of physical disabilities during treatment (63.4%), combined with the low cure rate, indicating weaknesses in clinical management and prevention and rehabilitation measures[26,27] Therefore, it is essential to strengthen longitudinal monitoring initiatives, integrating prevention and monitoring of existing physical disabilities.

Another critical point was the concentration of care at the DSPO, including among patients residing in areas covered by BHU. This referral pattern may reflect: (i) the population's historical perception that the DSPO, located in a building that formerly housed the leprosy referral hospital, offers "better" quality care; (ii) a preference for services located in the central region of the municipality, close to work and shops; (iii) the practice of frequent referrals from primary care units to the DSPO, especially for cases with PD, possibly due to the low training of health professionals in the clinical management of the disease.

Preliminary studies have confirmed that physicians and nurses demonstrate limited knowledge about the transmission, diagnosis, and clinical management of leprosy[28]. This finding is consistent with a qualitative study by Lana et al. (2014)[29] which identified health professionals who believe that the responsibility for leprosy control lies with specialized centers, not primary care services. This possible behavior allows us to understand the significantly higher prevalence of physical disabilities at the end of treatment among patients treated at DSPO (68.8%) compared to those treated at BHU (43.4%).

Decentralizing leprosy control actions, along with strengthening BHU, is a more effective strategy for expanding access, ensuring early diagnosis, and reducing physical disabilities rates. Additionally, an analysis conducted in Colombia and Brazil demonstrated that excessive centralization of services can lead to overburdening specialized centers and a disconnect from local needs[30,31].

It is important to highlight the fragility of information quality. Approximately 50.1% of cases could not be included in the analysis due to the lack of physical disabilities records at the end of treatment. Other studies have shown that the lack of PD records can lead to an underestimation of leprosy severity, compromise the quality of epidemiological surveillance, and hinder the planning of public health policies[15,32].

Finally, it is important to emphasize that prevention, clinical management, and the interruption of physical disabilities progression depend directly on the qualifications of health professionals. The National Policy for Continuing Health Education constitutes a strategic tool for transforming health practices, promoting the training and continuous updating of health workers[33].

CONCLUSION

The findings suggest late detection and highlight the need to strengthen Primary Health Care for early diagnosis and systematic follow-up of physical disabilities, starting at the time of diagnosis, in order to reduce the rates of physical disabilities at the end of treatment. It is also emphasized that it is necessary

to improve records on physical disabilities at the end of treatment, as well as to expand patient referrals in order to decentralize care.

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AUTHOR CONTRIBUTIONS

Study conception or design: Oliveira NG, Cortela DCB, Baptista IMFD. Data collection: Oliveira NG, Costa RM, Cortela DCB. Data analysis and interpretation: Oliveira NG, Cavalcante RS, Baptista IMFD. Article writing or critical review: Oliveira NG, Batista LC, Baptista IMFD. Final approval of the version to be published: Oliveira NG, Batista LC, Costa RM, Cortela DCB, Cavalcante RS, Baptista IMFD.

ACKNOWLEDGMENTS

Cáceres Municipal Health Department, Mato Grosso do Sul.

FUNDING

Coordination for the Improvement of Higher Education Personnel, Brazil (CAPES), Funding Code 001.

ETHICS APPROVAL

The study was approved by the Research and Ethics Committee of the Lauro de Souza Lima Institute, under opinion number 3,419,641, meeting national ethical standards for research involving human beings.

CONFLICT OF INTEREST

The authors declare no conflict of interest.