

Declining Leprosy-Related Hospitalization Rates and Increasing In-Hospital Case Fatality in Brazil: A Nationwide Ecological Time-Series Study, 2008-2023

Review began 09/29/2026

Review ended 10/15/2026

Published 10/22/2026

© Copyright 2026

de Souza et al. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

DOI: 10.7759/cureus.118367

Beatriz C. de Souza¹, Julia Bastos M. Dos Santos², Giovana G. Dantas³, Augusto A. Manfredi⁴, Verônica M. Franco⁵, Letícia C. Lopes⁶, Carolina C. Serafim⁷, Denise C. Pacheco⁶, Pablaine R. Bezerra⁸, Alana Leão⁹

1. School of Health Sciences, Universidade de Mogi das Cruzes, Mogi das Cruzes, BRA 2. Faculty of Medicine, Instituto de Educação Médica, Rio de Janeiro, BRA 3. School of Medicine, Centro Universitário de Volta Redonda, Volta Redonda, BRA 4. School of Medicine, Centro Universitário Fundação Assis Gurgacz, Cascavel, BRA 5. School of Medicine, Universidade de Ribeirão Preto, Ribeirão Preto, BRA 6. School of Medicine, Universidade de Rio Verde, Rio Verde, BRA 7. School of Medicine, Universidade de Marília, Marília, BRA 8. School of Medicine, Faculdade Metropolitana de Manaus, Manaus, BRA 9. Faculty of Medicine, Universidade Evangelica de Goiás, Anápolis, BRA

Corresponding author: Alana Leão, alanaleao321@gmail.com

Abstract

Background: Brazil reports more new leprosy cases than any country except India, yet whether the hospital burden of the disease has followed the decline in case detection is unknown.

Objective: The objective of this study is to describe trends in leprosy-related hospital admissions in Brazil from 2008 to 2023, and in their in-hospital case fatality, length of stay, and cost.

Methods: A nationwide ecological time-series study of all Brazilian Unified Health System (SUS) admissions with a primary diagnosis coded ICD-10 A30 (leprosy) or B92 (sequelae of leprosy), drawn from Hospital Information System microdata. Rates were directly standardized by age and sex to the 2022 Census population; costs were SUS reimbursements in constant 2023 Brazilian reais (R\$). Average annual percentage changes (AAPCs) were estimated by Prais-Winsten regression.

Results: Of 70,401 admissions, 1,026 (1.46%) ended in in-hospital death; reimbursements totaled R\$ 87.3 million. The standardized hospitalization rate fell from 3.08 to 1.61 per 100,000 (AAPC -6.18%; 95% CI -8.07 to -4.25), significantly in four of five macro-regions, from -2.86% per year in the Northeast to -11.07% in the Central-West; in the South, the confidence interval (CI) included zero. Annual deaths did not decline (47 in 2008, 64 in 2023), and case fatality rose from 1.03% to 1.89% (AAPC +5.51%; 95% CI +4.22 to +6.81); the population-based standardized death rate showed no statistically significant trend (AAPC -1.74%; 95% CI -3.74 to +0.30). Total cost fell by 4.45% per year (95% CI -7.33 to -1.49), and mean length of stay fell from 19.9 to 8.8 days. Cost per admission showed no significant trend over 2008-2023, but excluding 2008, when the national payment schedule changed, it fell by 1.41% per year (95% CI -2.28 to -0.53). Excluding sequelae (A30 only), the crude admission rate declined less and not significantly (AAPC -2.87%; 95% CI -6.23 to +0.62), whereas case fatality still rose (AAPC +4.09%; 95% CI +1.95 to +6.28). Most admissions were in men (46,068; 65.4%); 2,684 (3.8%) occurred before age 15.

Conclusions: Leprosy-related hospitalization rates declined, while in-hospital deaths did not, and case fatality among admitted patients increased. More severe disease among those admitted, changes in access or admission practice, and coding may each contribute to this divergence; these data cannot distinguish them.

Categories: Epidemiology/Public Health, Infectious Disease, Dermatology

Keywords: brazil, hansen's disease, health care costs, health services research, hospitalization, hospital mortality, leprosy, neglected tropical diseases, time series analysis, unified health system

Introduction

Leprosy remains endemic in Brazil, which consistently reports one of the highest numbers of new cases worldwide [1,2]. Sustained free multidrug therapy delivered through primary care has reduced new case detection, but the disease continues to generate irreversible peripheral nerve injury, deformity, and social exclusion [1,3]. Because the natural history of leprosy is dominated by slow nerve damage and by acute immune-mediated reactions that may occur before, during, or years after the completion of therapy, a substantial share of the clinical burden is expressed long after a patient ceases to be a notified incident case [4].

How to cite this article

de Souza B C, Dos Santos J M, Dantas G G, et al. (October 22, 2026) Declining Leprosy-Related Hospitalization Rates and Increasing In-Hospital Case Fatality in Brazil: A Nationwide Ecological Time-Series Study, 2008-2023. Cureus 18(10): e118367. DOI 10.7759/cureus.118367

Research on leprosy in Brazil has concentrated mainly on that notified incident case. Studies using the national notifiable disease system have mapped the socioeconomic determinants of new case detection [2,5], the incidence among household contacts [6], the spatial and temporal clustering of leprosy indicators [7], and the trend in grade 2 physical disability at diagnosis [8]; the Global Burden of Disease programme has estimated national years lived with disability [1]. The pandemic-era collapse in case detection has also been quantified [9]. What this literature does not describe is the burden that reaches hospital. Hospitalization for leprosy is not a marker of detection. It reflects clinical need, chiefly severe reactions, neuritis, secondary infection of anaesthetic limbs, and the sequelae captured separately in the ICD-10 as category B92, but it also reflects access to care, referral pathways, and admission practices. That burden falls on the Brazilian Unified Health System (SUS), and it has an explicit price.

Evidence on the economics of leprosy is likewise skewed. Household and out-of-pocket costs have been estimated in India, Ghana, and China [10-13], but these studies address expenditure by patients and families rather than expenditure by a health system, and none is Brazilian. Miguel and colleagues described leprosy morbidity and mortality in Brazil from 2008 to 2018 [3]; other Brazilian work has examined hospital admissions and costs for leprosy as one condition among several neglected tropical diseases in a single state [14], or over a shorter interval and without age standardization or cost deflation [15]. The present analysis covers 2008 to 2023, including the pandemic years, and combines admissions for active disease and for sequelae with direct age-sex standardization to an external census population, regional trend estimation, and inflation-adjusted hospital expenditure. Nationally, all-cause SUS admission rates and costs have been described [16], but leprosy was not examined separately. Consequently, it is not known whether the hospital burden of leprosy in Brazil has fallen in step with case detection, whether the patients who continue to be admitted resemble those admitted 15 years ago, or how much the system now spends on them.

We therefore analyzed 16 consecutive years of national hospital admission records to quantify trends in leprosy-related admissions, defined as admissions with a primary diagnosis coded ICD-10 A30 or B92, and in their in-hospital case fatality, length of stay, and inflation-adjusted cost, nationally and across Brazil's five macro-regions. We expected hospitalization rates and costs to decline in parallel with reported case detection; no direction was anticipated for case fatality or for cost per admission.

Materials And Methods

Study design and reporting

This was a nationwide, retrospective, ecological time-series study of routinely collected administrative health data covering 1 January 2008 to 31 December 2023. The period begins in 2008 because the national procedure and payment schedule of the SUS, which governs how hospital admissions are coded and reimbursed, changed in that year; records and monetary amounts from earlier years are not directly comparable with those that follow. Reporting follows the REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement, an extension of STROBE for this data type [17].

Data source and case definition

Hospital admission data were obtained from the Hospital Information System (Sistema de Informações Hospitalares, SIH/SUS) of the Brazilian Unified Health System, maintained by the Department of Informatics of the SUS (DATASUS) of the Brazilian Ministry of Health [18]. Rather than using the pre-aggregated TabNet morbidity tabulations, we downloaded the reduced hospital admission (RD) microdata files directly from the DATASUS public file transfer server and applied the case definition to the primary diagnosis field (DIAG_PRINC) of each record. This yielded 187,957,888 admission authorization records screened across the 16 years.

Inclusion was restricted to SUS hospital admission authorizations processed between January 2008 and December 2023 whose principal diagnosis field carried an ICD-10 code beginning with A30 (A30 and A30.0 to A30.9) or equal to B92; 74,132 records met this definition. Admissions in which leprosy or a leprosy complication appeared only as a secondary diagnosis, admissions financed outside the SUS, and records processed outside the study period were excluded. Throughout the article, "leprosy-related admissions" denotes this coded definition, not every hospitalization in which leprosy was clinically relevant. Consistent with DATASUS conventions, the count of admissions includes only type 1 (principal) authorizations, whereas deaths, hospital-days, and expenditure sum type 1 and type 5 (long-stay continuation) authorizations; the analytic admission count was therefore 70,401. Every episode carries exactly one type 1 authorization, and a death is recorded only on the authorization during which it occurs; earlier authorizations of the same stay close with a continuation exit, so no death is counted twice. The ratios of deaths, hospital-days, and expenditure to admissions are therefore per-episode quantities that do not depend on how many continuation authorizations an episode generates, except where the authorizations of one episode fall in different processing years. Records were assigned to a macro-region by the patient's municipality of residence and to a calendar year by year of processing, the field by which DATASUS organizes the files; assignment by date of admission would require files processed after 2023 to capture late-processed 2023 admissions, and was not undertaken. No included record lacked a valid age, sex, or municipality of residence, so the age-sex strata, the regions, and the national total reconcile exactly. The extraction

workbook, with the monthly file ledger and annual counts by diagnostic subcategory, is deposited with the code (see Data availability). A sensitivity analysis, built into the extraction at the outset, applied the narrower definition of ICD-10 A30 alone, which reproduces the case-mix of the DATASUS TabNet leprosy morbidity list.

Population denominators and age standardization

Denominators were the resident population by federative unit, sex, and five-year age band from the 2024 population projections of the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, IBGE) [19], aggregated to the five macro-regions across all 27 federative units. SIH and IBGE age classifications were harmonized to 17 common bands by collapsing "under 1 year" with "1-4 years" and all bands from 80 years upwards into "80 years or more".

Hospitalization rates were standardized by the direct method and expressed per 100,000 population. The standard population was the Brazilian resident population enumerated in the 2022 Demographic Census (203,080,756), cross-classified by the 17 age groups and sex [20]; the 34 resulting strata and their weights are given in Appendix 1. The same national standard was applied to Brazil and to every macro-region. The overall standardized rate applied the joint age-sex weights of that standard to the corresponding age- and sex-specific rates of each area and year; the male- and female-specific rates applied the within-sex age weights, so that the overall rate is the sex-weighted average of the two. Confidence intervals (CIs) for standardized rates were derived under a Poisson approximation for the variance of a weighted sum of rates.

Outcomes

The primary outcome was the trend in the standardized hospitalization rate. Secondary outcomes were the trends in the absolute number of admissions, in-hospital case-fatality (deaths divided by admissions), the standardized in-hospital death rate (deaths among admitted patients divided by the resident population, standardized by the same direct method), mean length of stay (hospital-days divided by admissions), total annual hospital cost, and mean cost per admission. Age and sex distributions of admissions were described for the pooled period.

Monetary values

Expenditure was the amount reimbursed by the SIH/SUS and was converted to constant 2023 Brazilian reais using the accumulated annual national consumer price index (Índice Nacional de Preços ao Consumidor Amplo, IPCA), compiled by the IBGE [21]. The deflator for each year was the product of $(1 + \text{annual IPCA})$ over all subsequent years to 2023. No discounting was applied, as the analysis describes realized expenditure rather than projected costs. Because the national procedure and payment schedule changed in January 2008, monetary trends are reported both for 2008–2023 and for 2009–2023, the latter excluding the transition year.

Statistical analysis

Annual values were log-transformed and regressed on calendar year by an iterative Prais-Winsten generalized least-squares procedure, which corrects for first-order serial autocorrelation by estimating the autocorrelation coefficient (ρ) from the residuals and transforming both the intercept and the slope terms of the design matrix, iterating to convergence of ρ . The average annual percentage change (AAPC) was calculated as $(e^{\hat{\rho}} - 1) \times 100$. Both the 95% CI and the p-value were derived from the same t-distribution with $n - 2$ degrees of freedom, so that the two statements always agree; ρ is reported for every model so that the adequacy of the correction can be judged. Because a single log-linear trend can misrepresent a series whose direction changes, each national series was additionally fitted with a continuous two-segment model, the change point chosen by grid search with a minimum of four observations per segment. The significance of the improvement was assessed by permutation over 2,000 replications, with the serial dependence of the series preserved: the residuals of the single-trend model were whitened at the estimated ρ of that series, permuted, and re-coloured through the same first-order autoregressive filter before refitting. Permuting raw residuals, as is conventional for series without autocorrelation correction, would instead test a null of no autocorrelation and would be anti-conservative here. Segment-specific annual percentage changes are reported with 95% confidence intervals from the two-segment fit, conditional on the estimated change point. Dependence of the primary result on the reference population was examined by repeating the identical procedure against two alternative standards, the national age-sex structure of 2008 and the pooled age-sex structure of the whole study period.

Because the records were analysed in aggregate, no individual-level covariates were available and no multivariable adjustment was possible; regional and sex-specific estimates are stratified analyses of aggregate series, not adjusted comparisons. No correction for multiple comparisons was applied: the primary outcome was defined in advance and the remaining outcomes are descriptive. Two-sided p-values below 0.05 were considered significant. The completeness ledger confirmed the full expected complement of 324 monthly files per year (27 federative units $\times$ 12 months) for all 16 years, with no missing or corrupted files and no records coded to the transitional ICD-10 code U99, so no imputation was required. That ledger establishes that no file was missing, which is not the same as establishing that the records inside those files

are complete or accurate.

Analyses were performed in Python 3.11 using NumPy, with the Prais-Winsten procedure implemented directly. The implementation was cross-validated against ordinary least squares and against the exact feasible generalized least-squares closed form, $\beta = (X'\Sigma^{-1}X)^{-1}X'\Sigma^{-1}y$ with Σ the first-order autoregressive correlation matrix at the converged ρ , which is an independent algebraic route; agreement was to machine precision. The estimates were also reproduced independently in R (R Foundation for Statistical Computing, Vienna, Austria), with identical results. Durbin-Watson statistics for the ordinary least-squares and for the transformed residuals of every modelled series are reported in Appendix 2, so that the need for the correction and its effect can both be judged. All analysis code and the complete annual series are publicly available (see Data availability). Two sensitivity analyses were performed: the narrower A30-only case definition, specified when the data were extracted, and a post hoc restriction to 2008-2019 excluding the COVID-19 pandemic. Because the extraction records the A30-only series by region and year but not by age and sex, trends under that definition are estimated for the crude admission rate and for case-fatality, and compared with the same crude measures under the main definition. The study was not registered, and no protocol was published in advance; apart from the primary outcome and the A30-only definition, the analyses are exploratory.

Ethics

The study used publicly available, anonymized, aggregate secondary data containing no information permitting individual identification. Under Brazilian National Health Council Resolution 510/2016, research using publicly accessible unidentified data is exempt from review by the research ethics system; no ethics committee approval or informed consent was required.

Data availability

The data underlying this study are publicly available: hospital admission records from the SIH/SUS reduced admission (RD) files distributed by DATASUS, Brazilian Ministry of Health [18]; population denominators from the IBGE 2024 population projections [19]; the standard population from the IBGE 2022 Demographic Census [20]; and the IPCA price index from the IBGE [21]. The harmonized analytic dataset, the complete annual series, all trend estimates, and the analysis and verification code generated for this study are deposited in Zenodo under an open licence [22].

Results

Overall burden

Between 2008 and 2023, there were 70,401 hospital admissions in Brazil with a primary diagnosis of leprosy or its sequelae, accounting for 825,184 hospital-days and 1,026 in-hospital deaths, a pooled in-hospital case fatality of 1.46% (1,026 of 70,401) and a pooled mean length of stay of 11.7 days (Table 1). Total expenditure was R\$ 55.9 million in nominal terms, equivalent to R\$ 87.3 million at 2023 prices, a mean of R\$ 1,241 per admission.

Region	Admissions, n (%)	Deaths, n	In-hospital case fatality, %	Total hospital-days	Mean LOS, days	Mean ASR per 100,000 (range)	Total cost, 2023 R\$ million	Mean cost/admission, 2023 R\$
Brazil (overall)	70,401 (100.0)	1,026	1.46	825,184	11.7	2.45 (1.25–3.74)	87.3	1,241
North	10,155 (14.4)	89	0.88	91,291	9.0	5.16 (2.04–10.08)	10.3	1,012
Northeast	22,154 (31.5)	420	1.90	229,834	10.4	2.83 (2.02–4.12)	24.0	1,083
Southeast	13,845 (19.7)	214	1.55	193,157	14.0	1.11 (0.44–2.12)	16.8	1,215
South	13,705 (19.5)	199	1.45	177,837	13.0	3.15 (0.85–6.72)	24.2	1,764
Central-West	10,542 (15.0)	104	0.99	133,065	12.6	5.56 (2.12–13.78)	12.0	1,143

TABLE 1: Volume, outcome, and cost of hospital admissions for leprosy and its sequelae, Brazil and macro-regions, 2008–2023

Values are totals pooled over the 16 study years, except the standardized rate, which is the mean of the 16 annual rates with the observed minimum and maximum in parentheses. Percentages of admissions are of the national total. Rates are standardized by the direct method to the 2022 Demographic Census population, by age and sex, and expressed per 100,000 [20]. Costs are in Brazilian reais at constant 2023 prices, deflated by the national consumer price index (IPCA) [21]. Admission counts include type 1 authorizations only, whereas deaths, hospital-days, and expenditure sum type 1 and type 5, following DATASUS convention. Regional case fatality rests on 89 to 420 deaths per region and is descriptive only. Cases were admissions with a primary diagnosis of leprosy (ICD-10 A30) or its sequelae (ICD-10 B92). ASR: age- and sex-standardized hospitalization rate; LOS: length of stay; R\$: Brazilian real. Source: Hospital Information System of the Brazilian Unified Health System (SIH/SUS-DATASUS), Brazilian Ministry of Health [18].

The Northeast accounted for the largest share of admissions (22,154; 31.5%), followed by the Southeast (13,845; 19.7%) and South (13,705; 19.5%). Absolute volume did not track standardized rates: the Southeast, with the second-largest number of admissions, had the lowest mean standardized rate of any region (1.11 per 100,000), whereas the Central-West and North, which together contributed 20,697 admissions (29.4%), had the highest (5.56 and 5.16 per 100,000, respectively).

Age and sex distribution

Admissions were predominantly in men (46,068; 65.4%) versus women (24,333; 34.6%), a ratio of 1.89:1; sex was recorded for every admission. The age distribution was concentrated in middle and older adulthood, with a mode at 50–54 years (6,570 admissions; 9.3%) and 19,286 admissions (27.4%) occurring between 45 and 59 years (Figure 1). Only 2,684 admissions (3.8%) occurred before age 15 years, whereas 21,507 (30.5%) occurred at age 60 years or older. Standardized rates were consistently higher in men, 4.32 against 1.92 per 100,000 in 2008 and 2.21 against 1.04 in 2023, a male-to-female rate ratio that changed little across the period (2.25 to 2.13). Both sexes declined at a similar pace (men -6.03% per year, 95% CI -7.51 to -4.52; women -6.44% per year, 95% CI -9.31 to -3.48; both p < 0.001) (Appendix 3).

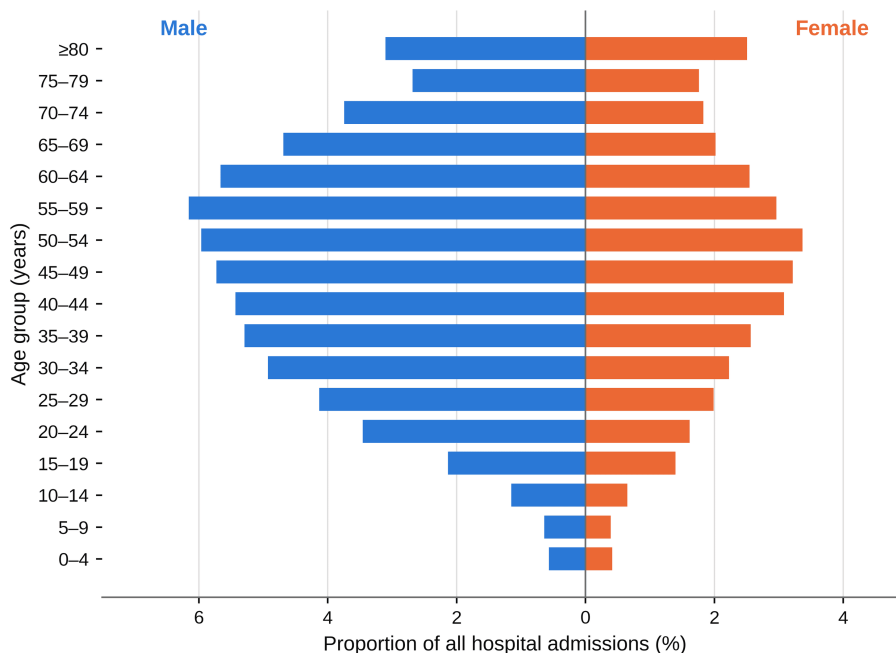


FIGURE 1: Age and sex distribution of hospital admissions for leprosy, Brazil, 2008-2023 (pooled)

Population pyramid of all hospital admissions with a primary diagnosis of leprosy (ICD-10 A30) or sequelae of leprosy (ICD-10 B92) over the study period. Bars to the left of the vertical axis (blue, labelled Male) and to the right (orange, labelled Female) show the percentage that each age–sex stratum contributes to the total number of admissions ($N = 70,401$; 46,068 male and 24,333 female, a male-to-female ratio of 1.89:1). Horizontal axis values are absolute percentages on both sides of the origin. Sex was recorded for every admission in the analysis period, so the age–sex strata shown here sum to the national total reported in Table 1. Source: SIH/SUS-DATASUS [18].

Primary outcome: standardized hospitalization rate

The national standardized hospitalization rate rose from 3.08 per 100,000 in 2008 to a peak of 3.74 per 100,000 in 2011, then declined to 1.61 per 100,000 in 2023 (Figure 2). Across the full series, the rate fell by an average of 6.18% per year (95% CI -8.07 to -4.25; $p = 0.142$; $p < 0.001$), a decline of 48.0% in the standardized rate between the first and last year. A two-segment model placed a change point at 2011, with the rate rising by 4.18% per year before it and falling by 7.65% per year after, but the improvement over the single trend was within chance (permutation $p = 0.167$), so the single trend was not shown to be inadequate (Appendix 4); that failure to demonstrate inadequacy is not itself evidence that the single trend is correct, and the specification is supported instead by the residual diagnostics (Appendix 2); the series minimum was reached in 2021 (1.25 per 100,000), with partial recovery to 2023. The crude rate fell more slowly (-4.55% per year, 95% CI -6.77 to -2.27; $p < 0.001$), a 33.0% fall against 48.0% for the standardized rate. The correction applied by standardization narrowed monotonically across the period, from +29.5% in 2008 to +9.9% in 2015 and +0.6% in 2023, as the population approached the age and sex structure of the standard (Figure 2). The absolute number of admissions fell from 4,556 to 3,378 (-3.89% per year, 95% CI -6.14 to -1.58; $p < 0.001$) (Table 2).

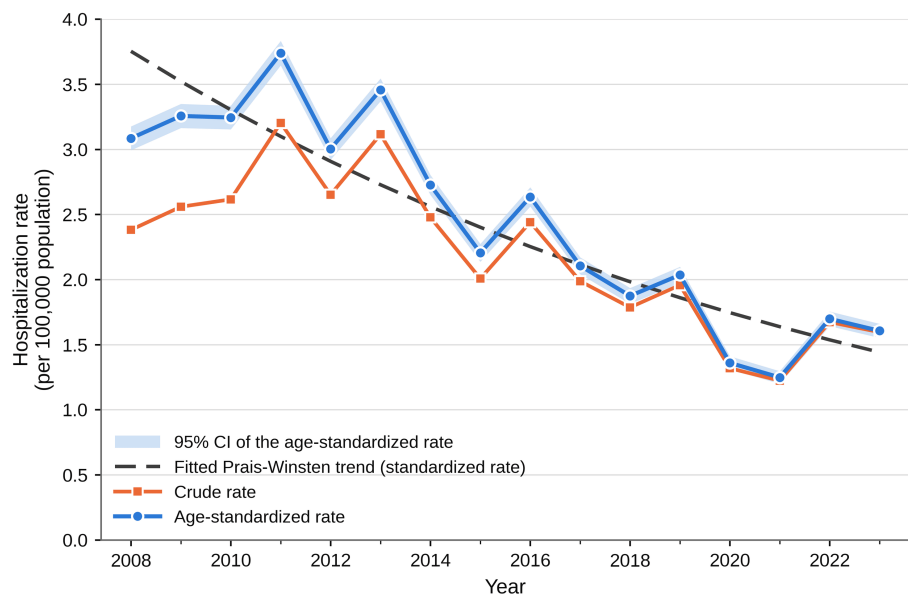


FIGURE 2: Crude and standardized hospitalization rates for leprosy, Brazil, 2008-2023

Orange line with square markers, crude hospitalization rate; blue line with circular markers, standardized rate; shaded blue band, 95% confidence interval of the standardized rate (Poisson approximation); dashed dark-grey line, fitted trend of the standardized rate from Prais-Winsten generalized least-squares regression on log-transformed values. Rates were standardized by the direct method to the Brazilian resident population enumerated in the 2022 Demographic Census, cross-classified by age and sex, and are expressed per 100,000 population [20]. Cases were hospital admissions with a primary diagnosis of leprosy (ICD-10 A30) or sequelae of leprosy (ICD-10 B92). CI: confidence interval; ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th Revision; ρ : first-order autocorrelation coefficient. Source: SIH/SUS-DATASUS [18].

Outcome	2008	2023	AAPC, % (95% CI)	p	p
Standardized hospitalization rate per 100,000 ^a	3.08	1.61	-6.18 (-8.07 to -4.25)	0.142	<0.001
Crude hospitalization rate per 100,000	2.38	1.60	-4.55 (-6.77 to -2.27)	0.234	<0.001
Hospital admissions, n	4,556	3,378	-3.89 (-6.14 to -1.58)	0.239	<0.001
Mean length of stay, days ^b	19.87	8.85	-4.67 (-8.61 to -0.56)	0.733	0.029
In-hospital case fatality, %	1.03	1.89	5.51 (4.22 to 6.81)	-0.401	<0.001
Total annual cost, 2023 R\$ million ^c	4.31	3.76	-4.45 (-7.33 to -1.49)	0.145	0.006
Mean cost per admission, 2023 R\$	947	1,114	-0.67 (-1.86 to 0.54)	-0.143	0.254
Standardized in-hospital death rate per 1,000,000 ^c	0.326	0.307	-1.74 (-3.74 to 0.30)	-0.242	0.088

TABLE 2: Trends in hospitalization rate, length of stay, in-hospital case fatality, and cost of leprosy-related admissions, Brazil, 2008–2023

Each row is a separate Prais-Winsten regression of one national annual series of log-transformed values on calendar year; p is the estimated first-order autocorrelation coefficient. Values for 2008 and 2023 are observed, not model-fitted. Rates are standardized by the direct method to the 2022 Demographic Census population, by age and sex, and expressed per 100,000 [20]. Costs are in constant 2023 Brazilian reais.

a: Primary outcome.

b: A single log-linear trend describes this series inadequately, as it changes direction within the period (Appendix 3); its AAPC is an average slope, not a constant annual rate.

c: Deaths among admitted patients divided by the resident population. Unlike in-hospital case fatality, its denominator does not depend on hospital use.

Cases were admissions with a primary diagnosis of leprosy (ICD-10 A30) or its sequelae (ICD-10 B92). AAPC: average annual percentage change; CI: confidence interval; R\$: Brazilian real. Source: Hospital Information System of the Brazilian Unified Health System (SIH/SUS-DATASUS), Brazilian Ministry of Health [18].

Regional trends

The point estimate of the trend was negative in all five macro-regions, and the decline reached statistical significance in four of them; the estimated magnitude varied almost fourfold (Table 3, Figure 3). The decline was steepest in the Central-West (-11.07% per year, 95% CI -14.71 to -7.28; p < 0.001), followed by the Southeast (-7.35%, 95% CI -10.18 to -4.42; p < 0.001) and North (-7.24%, 95% CI -10.87 to -3.47; p = 0.001). It was considerably shallower in the Northeast (-2.86%, 95% CI -4.90 to -0.78; p = 0.011). In the South, the point estimate was negative, but the CI crossed the null (-5.05%, 95% CI -12.75 to +3.33; p = 0.210), so no decline was demonstrated there; that series is markedly more volatile and included a mid-period rise to 6.72 per 100,000 in 2016.

Region	AAPC standardized rate, % (95% CI)	p	AAPC total cost, % (95% CI) ^a	p
Brazil (overall)	-6.18 (-8.07 to -4.25)	<0.001	-4.45 (-7.33 to -1.49)	0.006
North	-7.24 (-10.87 to -3.47)	0.001	-8.07 (-13.95 to -1.80)	0.016
Northeast	-2.86 (-4.90 to -0.78)	0.011	-3.11 (-6.71 to 0.62)	0.095
Southeast	-7.35 (-10.18 to -4.42)	0.210	-2.93 (-8.14 to 2.58)	0.268
South	-5.05 (-12.75 to 3.33)	0.189	2.65 (-5.59 to 11.60)	0.513
Central-West	-11.07 (-14.71 to -7.28)	<0.001	-12.96 (-17.35 to -8.33)	<0.001

TABLE 3: Trends in the standardized hospitalization rate and total hospital cost for leprosy, by macro-region, Brazil, 2008–2023

Each cell is a separate Prais-Winsten regression of one regional annual series of log-transformed values on calendar year. Rates are standardized by the direct method to the 2022 Demographic Census population, by age and sex, and expressed per 100,000 [20].

a: Total annual amount reimbursed by the SIH/SUS, in constant 2023 Brazilian reais.

Cases were admissions with a primary diagnosis of leprosy (ICD-10 A30) or its sequelae (ICD-10 B92). AAPC: average annual percentage change; CI: confidence interval. Source: Hospital Information System of the Brazilian Unified Health System (SIH/SUS-DATASUS), Brazilian Ministry of Health [18].

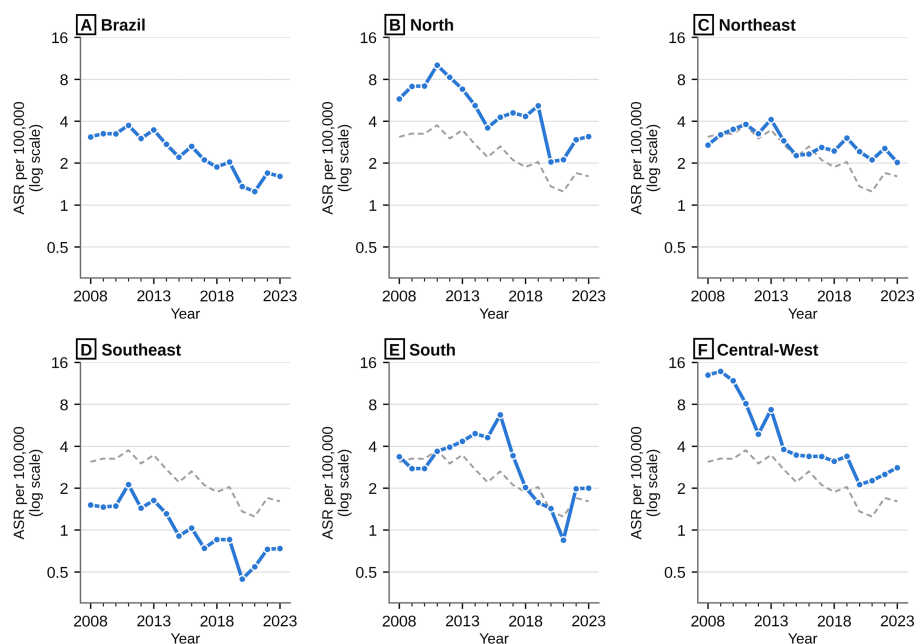


FIGURE 3: Standardized hospitalization rates for leprosy by Brazilian macro-region, 2008-2023

Six panels, lettered (A) Brazil, (B) North, (C) Northeast, (D) Southeast, (E) South, and (F) Central-West. In each panel, the blue line with circular markers is the standardized rate of the unit named in the panel heading; the grey dashed line reproduced in panels B to F is the national (Brazil) rate, shown as a common reference. Rates were standardized by the direct method to the age and sex structure of the Brazilian resident population enumerated in the 2022 Demographic Census and are expressed per 100,000 population [20]. Region-specific average annual percentage changes are reported in Table 3. ASR: age- and sex-standardized rate. Source: SIH/SUS-DATASUS [18].

The Central-West and North began the period with standardized rates of 12.95 and 5.78 per 100,000 and had converged towards the national value by 2023 (2.81 and 3.10). Regional heterogeneity in level therefore narrowed substantially, even as the Southeast remained the region with the lowest rates throughout.

Costs

Total inflation-adjusted hospital costs fell from R\$ 4.31 million in 2008 to R\$ 3.76 million in 2023, with a mid-period peak of R\$ 8.62 million in 2013 (Appendix 5). The average annual change was -4.45% (95% CI -7.33 to -1.49; $p = 0.145$; $p = 0.006$). Unlike the hospitalization rate, this series was better described by two segments than by one (permutation $p = 0.034$): costs rose by 17.53% per year up to a change point at 2011 and fell by 7.38% per year thereafter (Appendix 4). Regionally, the cost trend was significant in the Central-West (-12.96% per year, $p < 0.001$) and North (-8.07% per year, $p = 0.016$) but not in the Northeast (-3.11%, $p = 0.095$), Southeast (-2.93%, $p = 0.268$), or South (+2.65%, $p = 0.513$) (Table 3).

Cost per admission behaved differently from total cost. Nationally, it was R\$ 947 in 2008 and R\$ 1,114 in 2023 in constant terms, with no significant trend over the full series (-0.67% per year, 95% CI -1.86 to +0.54; $p = 0.254$) (Table 2). That result is conditional on the first year of the series, and the conditionality is material: real cost per admission rose by 49% between 2008 and 2009, from R\$ 947 to R\$ 1,409, a movement more consistent with the national procedure and payment schedule that took effect in 2008 than with any change in the care delivered. Excluding 2008, real cost per admission over 2009 to 2023 falls by 1.41% per year (95% CI -2.28 to -0.53; $p = 0.004$) and total real cost falls by 6.21% per year (95% CI -8.15 to -4.22; $p < 0.001$) rather than 4.45% (Table 2). A modest real decline in the cost of an admission is therefore the more cautious reading, and the finding of no change should not be reported without that qualification. The primary outcome does not depend on this choice, moving only from -6.18% to -6.85% per year when 2008 is excluded. The national figure also masked opposing regional movements: cost per admission fell significantly in the Central-West (-5.58% per year, $p < 0.001$), North (-4.90%, $p < 0.001$) and Northeast (-2.29%, $p = 0.005$), but rose in the South (+5.96% per year, 95% CI +4.55 to +7.39; $p < 0.001$), where it more than doubled from R\$ 1,027 to R\$ 2,259. The fall in total national cost was therefore driven by declining admission volume rather than by cheaper admissions.

Length of stay and in-hospital case fatality

Mean length of stay fell from 19.9 days in 2008 to 8.8 days in 2023 (Appendix 6). A single annual rate describes this series poorly. The two-segment model identified a change point at 2013, with stay shortening by 15.56% per year before it and remaining essentially flat afterwards (+0.91% per year); this specification removed 77.8% of the residual variance of the single-trend model (permutation $p = 0.032$; Appendix 4). This series carries the strongest serial dependence in the study ($\rho = 0.733$), and the permutation p is correspondingly sensitive to whether that dependence is preserved: it is 0.032 when it is, and below 0.001 when it is not. The reduction occurred in every region, ranging from -14.3% in the Southeast to -50.3% in the North.

Deaths did not follow admissions downward. The annual number of in-hospital deaths was 47 in 2008 and 64 in 2023 and never fell below 46, while admissions fell by 25.9%; in-hospital case fatality consequently rose from 1.03% to 1.89% (AAPC +5.51%, 95% CI +4.22 to +6.81; $p = -0.401$; $p < 0.001$) (Appendix 7), the highest value occurring in 2022 (2.75%, 97 deaths, the largest annual death count in the series despite the fourth-lowest admission volume). Measured against the resident population rather than against admissions, the standardized in-hospital death rate was 0.326 per 1,000,000 in 2008 and 0.307 in 2023, with an inconclusive trend over the period (AAPC -1.74%, 95% CI -3.74 to +0.30; $p = 0.088$) (Table 2), the interval excluding neither a meaningful decline nor stability. Regional death counts were small, from 89 to 420 per region over 16 years, so regional case fatality is reported descriptively only (Table 1).

Sensitivity analyses

Restricting the case definition to ICD-10 A30 alone, excluding sequelae, reduced the national case count from 70,401 to 56,063 (-20.4%) (Appendix 8). The contribution of B92 sequelae admissions varied by region, from 1,601 of 13,705 admissions (11.7%) in the South to 3,808 of 10,155 (37.5%) in the North. Under the A30-only definition, the national crude admission rate fell from 1.64 to 1.39 per 100,000, an AAPC of -2.87% (95% CI -6.23 to +0.62; $p = 0.098$), against -4.55% (95% CI -6.77 to -2.27) for the crude rate under the main definition. Part of the national decline therefore reflects fewer admissions coded to sequelae, which numbered 1,413 in 2008 and 438 in 2023. Regionally, the A30-only decline remained significant in the North (-5.57% per year; 95% CI -8.82 to -2.21) and the Central-West (-5.27%; 95% CI -7.58 to -2.90) (Appendix 8). In-hospital case fatality rose under both definitions: from 1.37% to 2.07% for A30 alone (AAPC +4.09%; 95% CI +1.95 to +6.28; $p = 0.001$). Expenditure is not recorded separately for the A30-only definition in the extraction and could not be re-estimated.

Restricting the series to 2008-2019 attenuated the national decline (-5.24% per year, 95% CI -7.53 to -2.89; $p < 0.001$, versus -6.18% for the full period), indicating that the pandemic years steepened but did not create the downward trend (Appendix 9). Regional estimates were more sensitive to this restriction: the Central-West decline was steeper in the pre-pandemic window (-13.74%, $p < 0.001$), whereas the North (-3.45%, $p = 0.272$) and Northeast (-1.58%, $p = 0.432$) lost statistical significance, indicating that for those two regions the full-period estimates depend materially on the low pandemic-era values. Replacing the census standard with the 2008 national age-sex structure, or with the pooled 2008-2023 structure, lowered the level of the rate in every year and attenuated the estimated decline (-5.42% and -5.80% per year, respectively, against -6.18%), because a standard drawn from within the study period is closer in age and sex composition to the

earlier years and therefore corrects them less (Appendix 10). The direction and statistical significance of the trend were unchanged under all three standards. Annual national counts and outcomes, on which every national trend estimate rests, are given in Appendix 11.

Discussion

In this nationwide analysis of 16 years of admission records, the standardized rate of leprosy-related hospitalization in Brazil fell by 6.2% per year and inflation-adjusted expenditure by 4.5% per year, whereas the annual number of in-hospital deaths did not decline and case fatality among admitted patients increased. The population-based in-hospital death rate showed no statistically significant trend. The real cost of an admission showed no significant trend over the full series and a modest decline once the 2008 payment-schedule transition was excluded. Part of the fall in admissions reflects fewer admissions coded to sequelae: under the A30-only definition the crude decline was smaller and not significant, whereas case fatality rose under both definitions. Mean length of stay halved, almost entirely before 2013.

The rise in case fatality is not an artefact of a shrinking denominator. Deaths did not fall as admissions fell, and the population-based death rate, which does not depend on hospital use, showed no significant change. These are deaths among hospitalized patients with leprosy, not deaths from leprosy. Leprosy is seldom the direct cause of death, and a death on an admission coded A30 or B92 may reflect comorbidity in an ageing population rather than the lethality of the disease.

One explanation is a change in who is admitted. If ambulatory multidrug therapy and outpatient management of mild reactions absorb the less severe presentations, the patients who still reach hospital are selected for severe disease: extensive type 2 reactions, acute neuritis, infected or ulcerated anaesthetic limbs, and complications in older patients with comorbidity [4]. The observation, raised in review, that most patients with leprosy reach hospital rarely and chiefly in an emergency describes the same mechanism from the other side. The hypothesis is consistent with our findings but cannot be tested with them, because these data carry no measure of clinical severity, comorbidity, or case mix. Other explanations are equally compatible with the data: changes in access to hospital care or in admission thresholds, so that fewer and sicker patients are admitted; changes in coding practice, including the balance between codes for active disease and for sequelae, which the A30-only analysis shows has shifted; and changes in patient composition, such as ageing and comorbidity. Distinguishing among them would require individual linkage of hospital records to the notification system, which records operational classification and disability grade. The concentration of admissions at older ages, with only 2,684 (3.8%) before age 15, is consistent with a burden driven by cumulative nerve damage and late complications rather than by incident disease in children.

The halving of length of stay was confined to the first six years of the series and had ended by 2013. Its magnitude and its presence in every region make a purely clinical explanation unlikely. The wind-down of long-stay institutional care in the former leprosy colonies is a plausible account, but it remains a hypothesis that these data cannot confirm. Reclassification of prolonged stays can be excluded: long-stay continuation authorizations became more frequent, not less, as stay shortened, from 14 to 94 qualifying records per year before 2011 (0.3% to 1.9%) to 349 to 457 per year in 2017-2020 (9.0% to 11.2%).

Notification-based surveillance has documented falling case detection with persistent concentration in the North, Northeast, and Central-West [7,15], and a stubborn burden of grade 2 disability at diagnosis [8]. Hospital data show the same regional gradient and the same overall decline and add a rising in-hospital case fatality that notification data cannot see. Studies in India, Ghana, and China have measured what families pay, documenting catastrophic household expenditure, particularly for reactions [10-13]. Our data measure the complementary quantity, what a universal public system reimburses for hospital care: R\$ 87.3 million over 16 years. The figure omits outpatient care, rehabilitation, productivity losses, and household costs; its interest lies in its trend and distribution rather than its size.

The regional results carry the clearest programmatic implication. The Northeast combines the largest number of admissions with the shallowest decline (-2.86% per year), and that decline lost statistical significance when the pandemic years were excluded. The South is the only region in which cost per admission rose steeply, more than doubling in real terms. These are the regions in which hospital burden is least clearly resolving, and plausible priorities for earlier diagnosis and outpatient management of reactions. An ecological design cannot identify which patients would benefit from which intervention, and we make no recommendation for clinical practice. Shorter, better-tolerated regimens now in clinical testing [23] may eventually change the severe end of the disease; their effect on hospital burden will need to be measured, not assumed.

The series minimum in 2020-2021 coincides with the collapse in case detection during the COVID-19 pandemic [9], and the partial recovery by 2022-2023 is consistent with resumed use of services. The national decline predates the pandemic and persists without it, but the estimates for the North and Northeast depend materially on pandemic-era values and should be regarded as provisional.

Strengths and limitations

The study includes every SUS admission in the country over 16 years, drawn from microdata rather than pre-aggregated tabulations, with no imputation. Rates are standardized to an enumerated external population, the 2022 Census, whose strata and weights are published with the paper; costs are deflated before any temporal comparison; and trends are corrected for serial autocorrelation, with ρ and residual diagnostics reported. The primary result did not depend on the choice of standard population.

The limitations are those of administrative data and of an ecological design. The case definition rests on the principal diagnosis, so admissions in which leprosy or a leprosy complication was recorded as a secondary diagnosis, or coded to its own ICD-10 chapter, are not captured. The study therefore describes coded admissions rather than all clinically leprosy-related hospitalizations and underestimates the hospital burden of the disease by an amount these data cannot quantify. Diagnoses are recorded for reimbursement and are not clinically validated, and secular drift in coding would be indistinguishable from a real trend. The completeness ledger shows that none of the files for the 192 study months were missing or corrupted; it does not show that the records within those files are complete or accurate. Records were assigned by year of processing, so an episode spanning a year boundary may contribute to adjacent years. Admissions rather than patients are counted, so readmissions are counted repeatedly, and per-patient burden cannot be estimated. No clinical detail is available: the reason for admission, operational classification, reaction type, disability grade, and comorbidity are unknown, and the proposed selection for severity cannot be confirmed. Deaths after discharge are not captured, so the mortality associated with severe leprosy is underestimated. Private-sector admissions are absent, although the SUS finances the large majority of leprosy care in Brazil. The cost measured is the SUS reimbursement for these admissions, not the economic burden of leprosy, which also comprises outpatient care, rehabilitation, productivity losses, and household expenditure. Annual denominators are population projections, the only series covering every year; the 2024 revision places the 2022 population at 210,862,983, which is 7,782,227 (3.8%) above the census count of 203,080,756, a difference attributed to census under-enumeration. If the projections overestimate the population, absolute rates are biased downward; because a single projection series is applied to every year, the trend is unlikely to be affected. Regional case fatality rests on small numbers of deaths and was not modelled. Finally, segmented regression did not show that a single log-linear trend is inadequate for the hospitalization rate, which is not the same as showing that it is adequate; it did show inadequacy for length of stay and total cost, for which the segmented estimates are reported alongside. With 16 annual observations, the position of a change point is imprecise.

Conclusions

In Brazil, the standardized rate of leprosy-related hospitalization declined over the study period, whereas case fatality among admitted patients increased and the annual number of in-hospital deaths did not fall. The population-based in-hospital death rate showed no statistically significant trend. Real expenditure fell with admission volume, and the real cost of an admission declined modestly once the 2008 payment-schedule transition is excluded. Part of the fall in admissions reflects fewer admissions coded to sequelae. Whether rising case-fatality reflects more severe disease among those admitted, changes in access or admission practice, or coding cannot be determined from these data; falling admission counts should not be read as evidence that the severe end of leprosy is resolving.

Appendices

Appendix 1

Age group (years)	Male, n	Female, n	Both sexes, n	Joint weight, male	Joint weight, female	Joint weight, both sexes	% of standard
0–4	6,461,689	6,243,171	12,704,860	0.031818	0.030742	0.062561	6.26
5–9	7,011,282	6,738,158	13,749,440	0.034525	0.033180	0.067704	6.77
10–14	6,992,746	6,682,215	13,674,961	0.034433	0.032904	0.067338	6.73
15–19	7,317,515	7,058,427	14,375,942	0.036033	0.034757	0.070789	7.08
20–24	7,767,306	7,699,157	15,466,463	0.038247	0.037912	0.076159	7.62
25–29	7,627,458	7,842,265	15,469,723	0.037559	0.038616	0.076175	7.62
30–34	7,537,285	7,935,832	15,473,117	0.037115	0.039077	0.076192	7.62
35–39	7,827,333	8,345,458	16,172,791	0.038543	0.041094	0.079637	7.96
40–44	7,781,059	8,291,111	16,072,170	0.038315	0.040827	0.079142	7.91
45–49	6,549,109	7,091,003	13,640,112	0.032249	0.034917	0.067166	6.72
50–54	6,014,391	6,584,190	12,598,581	0.029616	0.032422	0.062037	6.20
55–59	5,419,505	6,149,601	11,569,106	0.026686	0.030282	0.056968	5.70
60–64	4,605,834	5,338,555	9,944,389	0.022680	0.026288	0.048968	4.90
65–69	3,588,052	4,288,180	7,876,232	0.017668	0.021116	0.038784	3.88
70–74	2,615,350	3,243,186	5,858,536	0.012878	0.015970	0.028848	2.88
75–79	1,657,786	2,189,593	3,847,379	0.008163	0.010782	0.018945	1.89
≥80	1,758,731	2,828,223	4,586,954	0.008660	0.013927	0.022587	2.26
Total	98,532,431	104,548,325	203,080,756	0.485188	0.514812	1.000000	100.00

TABLE 4: Standard population used for direct standardization: Brazilian resident population enumerated in the 2022 Demographic Census, by age group and sex, with the joint age–sex weights applied to the rate for both sexes

The standard population is the Brazilian resident population enumerated in the 2022 Demographic Census (203,080,756 persons; 98,532,431 male and 104,548,325 female), Instituto Brasileiro de Geografia e Estatística, SIDRA table 9514. The joint weight of a stratum is its share of the whole standard population, $w(\text{age, sex}) = N(\text{age, sex}) / N(\text{total})$; the 34 joint weights sum to 1. The rate for both sexes is obtained by the direct method as $ASR = \sum w(\text{age, sex}) \times \text{admissions}(\text{age, sex}) / \text{population}(\text{age, sex}) \times 100,000$, the sum running over all 34 age–sex strata, where admissions and population are those observed in the area and year being standardized. The same national standard is applied to Brazil and to every macro-region, so that all rates are mutually comparable. The census classification was harmonized with that of the SIH/SUS into 17 age groups by combining 'under 1 year' with '1 to 4 years' and all groups from 80 years upwards into '≥80 years' [18–20]. Because the weights are proportions, the total size of the standard population does not affect the standardized rate; only the shape of its age and sex distribution does. ASR: age- and sex-standardized rate.

Age group (years)	Male, n	Within-male weight	Female, n	Within-female weight
0–4	6,461,689	0.065579	6,243,171	0.059716
5–9	7,011,282	0.071157	6,738,158	0.064450
10–14	6,992,746	0.070969	6,682,215	0.063915
15–19	7,317,515	0.074265	7,058,427	0.067514
20–24	7,767,306	0.078830	7,699,157	0.073642
25–29	7,627,458	0.077411	7,842,265	0.075011
30–34	7,537,285	0.076495	7,935,832	0.075906
35–39	7,827,333	0.079439	8,345,458	0.079824
40–44	7,781,059	0.078970	8,291,111	0.079304
45–49	6,549,109	0.066467	7,091,003	0.067825
50–54	6,014,391	0.061040	6,584,190	0.062977
55–59	5,419,505	0.055002	6,149,601	0.058821
60–64	4,605,834	0.046744	5,338,555	0.051063
65–69	3,588,052	0.036415	4,288,180	0.041016
70–74	2,615,350	0.026543	3,243,186	0.031021
75–79	1,657,786	0.016825	2,189,593	0.020943
≥80	1,758,731	0.017849	2,828,223	0.027052
Total	98,532,431	1.000000	104,548,325	1.000000

TABLE 5: Within-sex age weights applied to the male- and female-specific standardized rates, derived from the 2022 Demographic Census standard population

The within-sex weight is an age group's share of its own sex in the standard population, $w(\text{age} | \text{sex}) = N(\text{age, sex}) / N(\text{sex})$; each weight column sums to 1. The sex-specific rates of Table 7 in Appendices use these weights, whereas the rate for both sexes uses the joint weights of Table 4 in Appendices. Source of the standard population: Brazilian Institute of Geography and Statistics, 2022 Demographic Census, SIDRA table 9514 [20].

Appendix 2

Series	ρ	Slope, Prais-Winsten*	Slope, closed-form GLS*	Absolute difference	SE, Prais-Winsten	SE, closed-form GLS	Durbin-Watson, OLS residuals	Durbin-Watson, transformed residuals
Standardized hospitalization rate, Brazil	0.142	-0.063804	-0.063804	1.2E-16	0.009479	0.009479	1.58	1.82
Standardized hospitalization rate, North	0.265	-0.075160	-0.075160	8.3E-17	0.018585	0.018585	1.36	1.69
Standardized hospitalization rate, Northeast	0.174	-0.029017	-0.029017	2.4E-17	0.009896	0.009896	1.48	1.76
Standardized hospitalization rate, Southeast	0.181	-0.076323	-0.076323	2.8E-17	0.014493	0.014493	1.55	1.83
Standardized hospitalization rate, South	0.641	-0.051849	-0.051849	2.1E-17	0.039431	0.039431	0.73	1.79
Standardized hospitalization rate, Central-West	0.388	-0.117367	-0.117367	1.5E-16	0.019477	0.019477	1.19	1.90
Mean length of stay, Brazil	0.733	-0.047805	-0.047805	9.0E-17	0.019689	0.019689	0.54	1.77
In-hospital case fatality, Brazil	-0.401	0.053610	0.053610	1.4E-17	0.005724	0.005724	2.68	2.16
Total annual cost, Brazil	0.145	-0.045549	-0.045549	1.8E-15	0.014244	0.014244	1.36	1.66
Mean cost per admission, Brazil	-0.143	-0.006692	-0.006692	4.9E-16	0.005629	0.005629	1.79	1.52
Standardized rate, men, Brazil	0.054	-0.062173	-0.062173	7.6E-17	0.007417	0.007417	1.75	1.83
Standardized rate, women, Brazil	0.261	-0.066567	-0.066567	5.6E-17	0.014502	0.014502	1.37	1.80

TABLE 6: Validation of the Prais-Winsten estimator and residual diagnostics

Slopes and standard errors from the iterative Prais-Winsten transformation are compared with the exact feasible GLS solution, $\beta = (X'\Sigma^{-1}X)^{-1}X'\Sigma^{-1}y$, with Σ the AR(1) correlation matrix at the converged ρ . Durbin-Watson values near 2 indicate no residual first-order autocorrelation. *Slope of $\ln(\text{value})$ on calendar year; AAPC = $(e^{\text{slope}} - 1) \times 100$.

AAPC: average annual percentage change; AR(1): first-order autoregressive; GLS: generalized least squares; OLS: ordinary least squares; SE: standard error; ρ : first-order autocorrelation coefficient. Cases: admissions with a principal diagnosis of ICD-10 A30 or B92. Source: SIH/SUS-DATASUS, Brazilian Ministry of Health [18].

Appendix 3

Year	Both sexes	Male	Female	Male-to-female ratio
2008	3.08	4.32	1.92	2.25
2009	3.26	4.56	2.03	2.25
2010	3.24	4.44	2.12	2.10
2011	3.74	4.72	2.82	1.67
2012	3.00	3.94	2.12	1.85
2013	3.46	4.60	2.38	1.93
2014	2.73	3.61	1.89	1.91
2015	2.20	2.85	1.60	1.78
2016	2.63	3.41	1.91	1.79
2017	2.11	2.91	1.35	2.16
2018	1.87	2.52	1.27	1.99
2019	2.03	2.68	1.43	1.87
2020	1.36	1.95	0.80	2.44
2021	1.25	1.81	0.72	2.51
2022	1.70	2.38	1.06	2.24
2023	1.61	2.21	1.04	2.13

TABLE 7: Annual standardized hospitalization rate for leprosy by sex, Brazil, 2008–2023

The rate for both sexes uses the joint age–sex weights of the standard population (Table 4 in Appendices); the male- and female-specific rates use the within-sex age weights (Table 5 in Appendices). Rates are standardized by the direct method to the 2022 Demographic Census population, by age and sex, and expressed per 100,000 [20]. Cases were admissions with a primary diagnosis of leprosy (ICD-10 A30) or its sequelae (ICD-10 B92). Source: Hospital Information System of the Brazilian Unified Health System (SIH/SUS-DATASUS), Brazilian Ministry of Health [18].

Appendix 4

Outcome	Change point	APC before, % (95% CI)	APC after, % (95% CI)	Residual variance explained, %	Permutation p
Standardized hospitalization rate	2011	4.18 (-5.80 to 15.23)	-7.65 (-9.58 to -5.69)	29.0	0.167
Mean length of stay	2013	-15.56 (-19.14 to -11.82)	0.91 (-1.07 to 2.92)	77.8	0.032
Total annual cost (2023 R\$)	2011	17.53 (3.52 to 33.45)	-7.38 (-9.80 to -4.89)	50.1	0.034

TABLE 8: Two-segment regression of the national annual series, Brazil, 2008–2023

Continuous two-segment log-linear models, with the change point chosen by grid search and at least 4 observations per segment. Permutation p values (2,000 replications) preserve serial dependence: residuals were whitened at each series' p before permutation. A nonsignificant p value means that no improvement over a single trend was shown, not that a single trend is adequate. With 16 observations, the location of a change point is imprecise. Segment APCs are from the two-segment fit, with 95% CIs from the t distribution (13 df), conditional on the change point.

APC: annual percentage change within a segment; p: first-order autocorrelation coefficient; R\$: Brazilian real. Cases: admissions with a principal diagnosis of ICD-10 A30 or B92. Source: SIH/SUS-DATASUS, Brazilian Ministry of Health [18].

Appendix 5

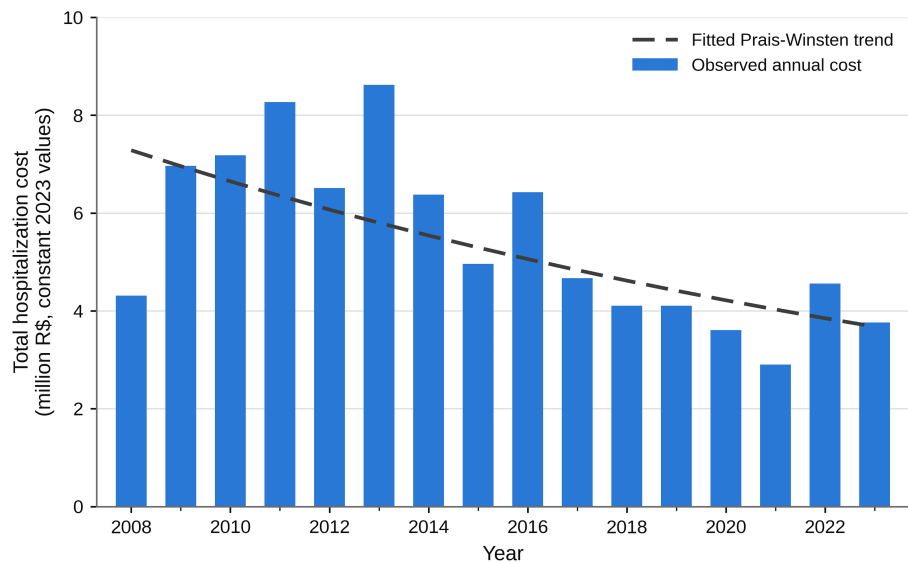


FIGURE 4: Annual hospitalization costs for leprosy, Brazil, 2008-2023, in constant 2023 Brazilian reais

Blue bars, total annual amount reimbursed by SIH/SUS for hospital admissions with a primary diagnosis of leprosy (ICD-10 A30) or sequelae of leprosy (ICD-10 B92); dashed dark-grey line, fitted trend from Prais-Winsten generalized least-squares regression on log-transformed annual costs. All monetary values were deflated to constant 2023 Brazilian reais (R\$) using the accumulated annual Índice Nacional de Preços ao Consumidor Amplo (IPCA), so that values are directly comparable across years [21]. CI: confidence interval; IPCA: Brazilian Broad National Consumer Price Index; R\$: Brazilian real; p: first-order autocorrelation coefficient. Source: SIH/SUS-DATASUS [18].

Appendix 6

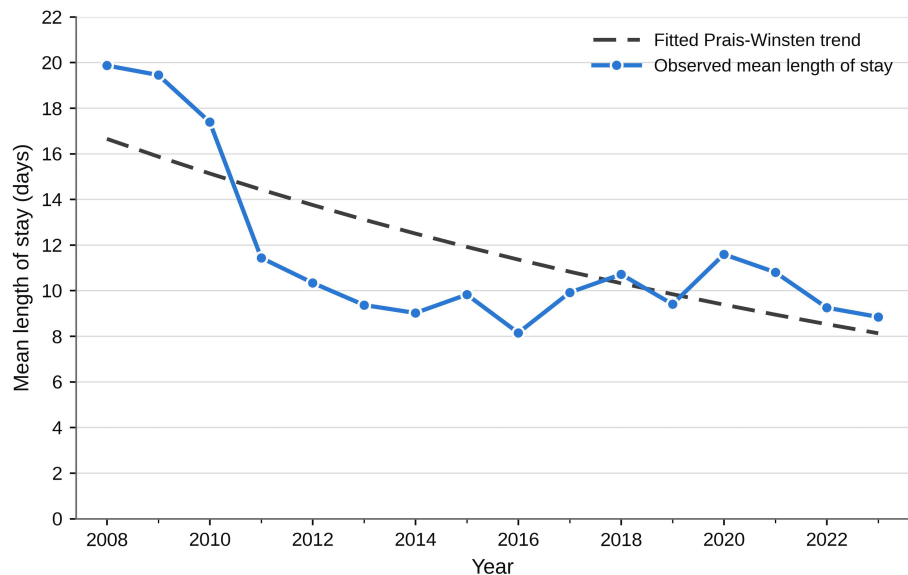


FIGURE 5: Mean length of hospital stay for leprosy-related admissions, Brazil, 2008-2023

Observed annual mean length of stay (solid blue line with circles) and the fitted trend from Prais-Winsten regression on log-transformed annual values (dashed grey line). Mean length of stay is hospital-days divided by admissions. Because the series changes slope at 2013, the fitted line represents an average slope rather than a constant annual rate; segment estimates are given in Appendix 4. Source: SIH/SUS-DATASUS, Brazilian Ministry of Health [18]; admissions with a principal diagnosis of ICD-10 A30 or B92.

Appendix 7

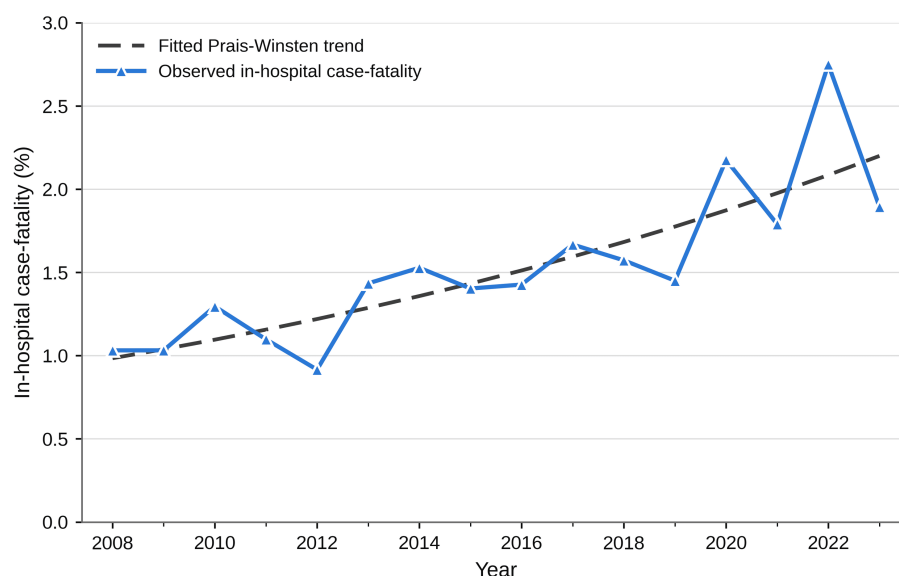


FIGURE 6: In-hospital case fatality for leprosy-related admissions, Brazil, 2008-2023

Blue line with triangular markers, observed annual in-hospital case fatality (deaths during the admission divided by admissions); dashed dark-grey line, fitted trend from Prais-Winsten generalized least-squares regression on log-transformed annual values. AAPC: average annual percentage change; CI: confidence interval; ρ : first-order autocorrelation coefficient. Source: SIH/SUS-DATASUS, admissions with a primary diagnosis of ICD-10 A30 or B92 [18].

Appendix 8

Region	Admissions, A30 + B92, n [*]	Admissions, A30 only, n [†]	Difference, n (%)	Crude-rate AAPC, A30 + B92, % (95% CI)	Crude-rate AAPC, A30 only, % (95% CI)
Brazil (overall)	70,401	56,063	14,338 (20.4)	-4.55 (-6.77 to -2.27)	-2.87 (-6.23 to 0.62)
North	10,155	6,347	3,808 (37.5)	-5.06 (-8.83 to -1.14)	-5.57 (-8.82 to -2.21)
Northeast	22,154	19,278	2,876 (13.0)	-1.44 (-3.79 to 0.97)	0.02 (-3.64 to 3.82)
Southeast	13,845	10,754	3,091 (22.3)	-5.79 (-8.89 to -2.59)	-3.75 (-8.54 to 1.30)
South	13,705	12,104	1,601 (11.7)	-3.29 (-11.50 to 5.68)	-4.04 (-11.69 to 4.26)
Central-West	10,542	7,580	2,962 (28.1)	-9.14 (-11.90 to -6.29)	-5.27 (-7.58 to -2.90)

TABLE 9: Leprosy admissions and crude admission-rate trends under two case definitions, Brazil and macro-regions, 2008–2023

The difference between the two count columns is the contribution of admissions coded to sequelae. Trends are for crude rates per 100,000 under both definitions, because the A30-only series is not available by age and sex; Each AAPC is from a separate Prais-Winsten regression of the log-transformed annual series on calendar year; 95% CIs and p-values are from the t distribution.

*Principal diagnosis ICD-10 A30 or B92; the study definition.

†Principal diagnosis ICD-10 A30 only; reproduces the DATASUS TabNet leprosy morbidity list.

AAPC: average annual percentage change; CI: confidence interval. Source: SIH/SUS-DATASUS, Brazilian Ministry of Health [18].

Appendix 9

Region	AAPC 2008–2023, % (95% CI)	p	AAPC 2008–2019, % (95% CI)	p
Brazil (overall)	-6.18 (-8.07 to -4.25)	<0.001	-5.24 (-7.53 to -2.89)	<0.001
North	-7.24 (-10.87 to -3.47)	0.001	-3.45 (-9.74 to 3.27)	0.272
Northeast	-2.86 (-4.90 to -0.78)	0.011	-1.58 (-5.77 to 2.79)	0.432
Southeast	-7.35 (-10.18 to -4.42)	<0.001	-6.99 (-10.64 to -3.18)	0.002
South	-5.05 (-12.75 to 3.33)	0.210	-5.27 (-16.64 to 7.66)	0.368
Central-West	-11.07 (-14.71 to -7.28)	<0.001	-13.74 (-17.91 to -9.36)	<0.001

TABLE 10: Trend in the standardized hospitalization rate for leprosy with and without the COVID-19 pandemic years, Brazil and macro-regions

The restricted series ends in 2019 and therefore excludes the COVID-19 pandemic. Each AAPC is from a separate Prais-Winsten regression of the log-transformed annual series on calendar year; 95% CIs and p values are from the t distribution. Rates per 100,000, directly standardized by age and sex to the 2022 Census population [20].

AAPC: average annual percentage change; CI: confidence interval. Cases: admissions with a principal diagnosis of ICD-10 A30 or B92. Source: SIH/SUS-DATASUS, Brazilian Ministry of Health [18].

Appendix 10

Standard population	Rate 2008	Rate 2023	AAPC, % (95% CI)	p
2022 Demographic Census (primary analysis)	3.08	1.61	-6.18 (-8.07 to -4.25)	<0.001
2008 national age–sex structure	2.38	1.38	-5.42 (-7.56 to -3.24)	<0.001
Pooled 2008–2023 age–sex structure	2.71	1.49	-5.80 (-7.80 to -3.75)	<0.001

TABLE 11: Standardized hospitalization rate for leprosy under three alternative standard populations, Brazil, 2008–2023

All three rows use the identical direct method and the same joint age–sex weighting and differ only in the population supplying the weights: the 2022 census is external to the series, the other two standards are internal to it. Rates are per 100,000. Cases were admissions with a primary diagnosis of leprosy (ICD-10 A30) or its sequelae (ICD-10 B92).

AAPC: average annual percentage change; CI: confidence interval. Source: Hospital Information System of the Brazilian Unified Health System (SIH/SUS-DATASUS), Brazilian Ministry of Health [18].

Appendix 11

Year	Admissions, n	Deaths, n	Case fatality, %	Hospital-days, n	Mean LOS, days	Total cost, 2023 R\$ million	Cost per admission, 2023 R\$	Crude rate per 100,000	Standardized rate per 100,000
2008	4,556	47	1.03	90,519	19.87	4.31	947	2.38	3.08
2009	4,943	51	1.03	96,149	19.45	6.96	1,409	2.56	3.26
2010	5,094	66	1.30	88,579	17.39	7.18	1,410	2.62	3.24
2011	6,283	69	1.10	71,857	11.44	8.27	1,316	3.20	3.74
2012	5,241	48	0.92	54,199	10.34	6.51	1,242	2.65	3.00
2013	6,206	89	1.43	58,141	9.37	8.62	1,389	3.12	3.46
2014	4,974	76	1.53	44,861	9.02	6.38	1,282	2.48	2.73
2015	4,062	57	1.40	39,909	9.82	4.96	1,221	2.01	2.20
2016	4,976	71	1.43	40,543	8.15	6.43	1,292	2.44	2.63
2017	4,078	68	1.67	40,437	9.92	4.67	1,145	1.99	2.11
2018	3,688	58	1.57	39,517	10.72	4.11	1,113	1.79	1.87
2019	4,068	59	1.45	38,255	9.40	4.11	1,009	1.96	2.03
2020	2,757	60	2.18	31,953	11.59	3.61	1,308	1.32	1.36
2021	2,570	46	1.79	27,762	10.80	2.90	1,130	1.22	1.25
2022	3,527	97	2.75	32,623	9.25	4.56	1,292	1.67	1.70
2023	3,378	64	1.89	29,880	8.85	3.76	1,114	1.60	1.61

TABLE 12: Annual leprosy-related admissions and outcomes, Brazil, 2008–2023

Admissions count principal (type 1) authorizations; deaths, hospital-days, and costs also include long-stay continuation (type 5) authorizations. Case fatality: deaths/admissions. Costs are SUS reimbursements in constant 2023 R\$, deflated by the IPCA [21]. Rates per 100,000, directly standardized by age and sex to the 2022 Census population [20].

IPCA: Brazilian national consumer price index; LOS: length of stay; R\$: Brazilian real. Cases: admissions with a principal diagnosis of ICD-10 A30 or B92. Source: SIH/SUS-DATASUS, Brazilian Ministry of Health [18].

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Alana Leão, Beatriz C. de Souza

Acquisition, analysis, or interpretation of data: Alana Leão, Beatriz C. de Souza, Julia Bastos M. Dos Santos, Giovana G. Dantas, Augusto A. Manfredi, Verônica M. Franco, Letícia C. Lopes, Carolina C. Serafim, Denise C. Pacheco, Pablíane R. Bezerra

Drafting of the manuscript: Alana Leão, Beatriz C. de Souza, Julia Bastos M. Dos Santos, Giovana G. Dantas, Augusto A. Manfredi, Verônica M. Franco, Letícia C. Lopes, Carolina C. Serafim, Denise C. Pacheco, Pablíane R. Bezerra

Critical review of the manuscript for important intellectual content: Alana Leão, Beatriz C. de Souza, Julia Bastos M. Dos Santos

Supervision: Beatriz C. de Souza

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all

participants in this study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. de Araújo VE, Veloso GA, Kerr LR, Pescarini JM, Cardoso LS, Naghavi M, Malta DC: Leprosy in Brazil: an analysis of the Global Burden of Disease estimates between 1990 and 2019. *Public Health*. 2024, 236:307-14. [10.1016/j.puhe.2024.07.035](https://doi.org/10.1016/j.puhe.2024.07.035)
2. Nery JS, Ramond A, Pescarini JM, et al.: Socioeconomic determinants of leprosy new case detection in the 100 Million Brazilian Cohort: a population-based linkage study. *Lancet Glob Health*. 2019, 7:e1226-36. [10.1016/S2214-109X\(19\)30260-8](https://doi.org/10.1016/S2214-109X(19)30260-8)
3. Miguel CB, da Mota PB, Afonso BO, et al.: Leprosy morbidity and mortality in Brazil: 2008-2018. *Braz J Infect Dis*. 2021, 25:101638. [10.1016/j.bjid.2021.101638](https://doi.org/10.1016/j.bjid.2021.101638)
4. Mehta H, Jain S, Narang T, Chhabra S, Dogra S: Leprosy reactions: new knowledge on pathophysiology, diagnosis, treatment and prevention. *Indian J Dermatol Venereol Leprol*. 2025, 91:470-81. [10.25259/IJDVL_915_2024](https://doi.org/10.25259/IJDVL_915_2024)
5. Pescarini JM, Strina A, Nery JS, et al.: Socioeconomic risk markers of leprosy in high-burden countries: a systematic review and meta-analysis. *PLoS Negl Trop Dis*. 2018, 12:e0006622. [10.1371/journal.pntd.0006622](https://doi.org/10.1371/journal.pntd.0006622)
6. Teixeira CS, Pescarini JM, Alves FJ, et al.: Incidence of and factors associated with leprosy among household contacts of patients with leprosy in Brazil. *JAMA Dermatol*. 2020, 156:640-8. [10.1001/jamadermatol.2020.0653](https://doi.org/10.1001/jamadermatol.2020.0653)
7. Paz WS, Ramos RE, Bezerra LP, et al.: Temporal trend, high-risk spatial and spatiotemporal clustering of leprosy indicators in Brazil: a 20-year ecological and population-based study. *Trop Med Int Health*. 2023, 28:517-29. [10.1111/tmi.13901](https://doi.org/10.1111/tmi.13901)
8. Matos TS, de Souza CD, de Oliveira Fernandes TR, et al.: Time trend and identification of risk areas for physical disability due to leprosy in Brazil: an ecological study, 2001-2022. *BMC Infect Dis*. 2025, 25:320. [10.1186/s12879-025-10586-2](https://doi.org/10.1186/s12879-025-10586-2)
9. da Paz WS, Souza MD, Tavares DD, et al.: Impact of the COVID-19 pandemic on the diagnosis of leprosy in Brazil: an ecological and population-based study. *Lancet Reg Health Am*. 2022, 9:100181. [10.1016/j.lana.2021.100181](https://doi.org/10.1016/j.lana.2021.100181)
10. Tiwari A, Suryawanshi P, Raikwar A, Arif M, Richardus JH: Household expenditure on leprosy outpatient services in the Indian health system: a comparative study. *PLoS Negl Trop Dis*. 2018, 12:e0006181. [10.1371/journal.pntd.0006181](https://doi.org/10.1371/journal.pntd.0006181)
11. Chandler DJ, Hansen KS, Mahato B, Darlong J, John A, Lockwood DN: Household costs of leprosy reactions (ENL) in rural India. *PLoS Negl Trop Dis*. 2015, 9:e0003431. [10.1371/journal.pntd.0003431](https://doi.org/10.1371/journal.pntd.0003431)
12. Dalaba MA, Manyeh AK, Immurana M, et al.: The economic burden of leprosy treatment to households in Ghana: a cross-sectional study in the Volta Region of Ghana. *SAGE Open Med*. 2024, 12:20503121241281424. [10.1177/20503121241281424](https://doi.org/10.1177/20503121241281424)
13. Xiong M, Li M, Zheng D, Wang X, Su T, Chen Y, Yang B: Evaluation of the economic burden of leprosy among migrant and resident patients in Guangdong Province, China. *BMC Infect Dis*. 2017, 17:760. [10.1186/s12879-017-2869-8](https://doi.org/10.1186/s12879-017-2869-8)
14. Brito SP, Lima MD, Ferreira AF, Ramos AN Jr: Hospital admissions due to neglected tropical diseases in Piauí, in the Northeast region of Brazil: costs, time trends, and spatial patterns, 2001-2018 (Article in Portuguese). *Cad Saude Publica*. 2022, 38:e00281021. [10.1590/0102-311XPT281021](https://doi.org/10.1590/0102-311XPT281021)
15. Costa HD, Tecchio DW, Souza EB, Santos JE: Hanseníase na região Norte do Brasil: epidemiologia das interações nos últimos dez anos, 2013-2022 (Article in Portuguese). *Braz J Health Rev*. 2023, 6:10916-24. [10.34119/bjhrv6n3-199](https://doi.org/10.34119/bjhrv6n3-199)
16. Zhao Q, Coelho MS, Li S, Saldiva PH, Abramson MJ, Huxley RR, Guo Y: Trends in hospital admission rates and associated direct healthcare costs in Brazil: a nationwide retrospective study between 2000 and 2015. *Innovation (Camb)*. 2020, 1:100013. [10.1016/j.xinn.2020.04.013](https://doi.org/10.1016/j.xinn.2020.04.013)
17. Benchimol EI, Smeeth L, Guttman A, et al.: The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement. *PLoS Med*. 2015, 12:e1001885. [10.1371/journal.pmed.1001885](https://doi.org/10.1371/journal.pmed.1001885)
18. Ministry of Health of Brazil, Department of Informatics of the Unified Health System (DATASUS): Hospital Information System of the Unified Health System (SIH/SUS), reduced hospital admission files (RD). (2026). Accessed: September 01, 2026: <https://datasus.saude.gov.br/transferencia-de-arquivos/>.
19. Brazilian Institute of Geography and Statistics (IBGE): Population projections for Brazil and the federative units by sex and age, 2000-2070, 2024 revision. (2024). Accessed: September 01, 2026: <https://www.ibge.gov.br/estatisticas/sociais/populacao/9109-projecao-da-populacao.html>.
20. Brazilian Institute of Geography and Statistics (IBGE): 2022 Demographic Census. Resident population, by sex, age and form of age declaration (SIDRA table 9514). (2023). Accessed: September 01, 2026: <https://sidra.ibge.gov.br/tabela/9514>.
21. Brazilian Institute of Geography and Statistics (IBGE): Extended National Consumer Price Index (IPCA), annual historical series. (2026). Accessed: September 14, 2026: <https://www.ibge.gov.br/en/statistics/economic/prices-and-costs/17129-extended-national-consumer-price-index.html>.
22. de Souza BC, Dos Santos JB, Dantas GG, et al.: Code and data for: declining leprosy-related hospitalization

- rates and increasing in-hospital case-fatality in Brazil: a nationwide ecological time-series study, 2008-2023. Zenodo. 2026, [10.5281/zenodo.23383923](https://zenodo.org/record/23383923)
23. Barreto J, Sammarco Rosa P, Adams L, et al.: Bedaquiline monotherapy for multibacillary leprosy. *N Engl J Med*. 2024, 391:2212-8. [10.1056/NEJMoa2312928](https://doi.org/10.1056/NEJMoa2312928)