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Beyond Numbers, Toward Solutions: Clinico-Epidemiological Insights from Five Years of Evolving Leprosy Patterns in the Post-Pandemic Era (2020-2024)

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A B S T R A C T

Background: Leprosy continues to be a public health focus in endemic countries, with encouraging progress and ongoing opportunities for improved elimination strategies. This study provides an in-depth assessment of clinico-epidemiological trends and outcomes observed from 2020–2024 at a tertiary care center, offering valuable insights into post-pandemic disease patterns and solution-oriented approaches. **Methods:** This retrospective review encompassed all new leprosy cases over five years, utilizing advanced statistical methodologies including time series analysis, trend assessment, and regression modelling. Demographic, clinical, reactional, disability, and rehabilitation data were carefully collected and analysed using descriptive statistics, comparative analyses, and longitudinal trend evaluations. **Results:** Five hundred twenty-three new leprosy cases were identified (2020–2024) with discernible temporal variation. Multibacillary (MB) presentations predominated (95.6%, n=500), demonstrating the importance of ongoing early detection initiatives. Males accounted for 57.5% of cases, yet a narrowing gender gap was observed, reflecting positive developments in healthcare access. Grade 2 disability (G2D) rates averaged 17.0%, peaking at 19.7% in 2023, suggesting opportunities for further enhancement of preventive efforts. Leprosy reactions increased over six-fold in the period, highlighting the need for vigilant management strategies. Paediatric cases formed 5.9% of the cohort, with a 29.0% disability rate, pointing to areas for focused intervention. **Conclusions:** Commendable advances in leprosy control and management are evident. Continued progress will benefit from intensified early case detection, expanded disability prevention, and robust reaction management—cornerstones for achieving national and global elimination goals.

Keywords: Leprosy, epidemiology, multibacillary, disability, reactions, elimination, post-pandemic

Introduction

Leprosy, caused by *Mycobacterium leprae*, remains a health focus in regions with ongoing transmission. Through decades of dedicated strategies and multidrug therapy (MDT), remarkable reductions in global disease prevalence have been achieved[1, 2]. Despite these strides—from over 5 million cases in the 1980s to about 200,000 registered cases in 2021—periodic assessments show that continued vigilance is required, particularly in prevention of disability and early detection among children and adults alike[3, 4].

The World Health Organization's Global Leprosy Strategy 2021–2030 emphasizes "zero disability" and "zero discrimination" through person-centered, integrated care and meaningful community involvement[5]. Attainment of these ambitious benchmarks will be facilitated by in-depth understanding of evolving epidemiological patterns, especially as health systems adapt in the post-pandemic era[6,7].

Profiling clinico-epidemiological features, including disease spectrum, disability gradation, gender dynamics, and the uptake of key interventions, is critical to guiding robust, evidence-based elimination efforts[8,9]. While contemporary studies have described persistent trends in multibacillary cases and disability rates[10],[11], the landscape is positively evolving thanks

to continuous program innovation and system-wide adaptation following the COVID-19 pandemic, which temporarily affected case-finding and service delivery[12,13].

This study provides a comprehensive, five-year reflection on new leprosy cases in a tertiary setting, offering multi-dimensional analysis and practical recommendations to inform ongoing program strengthening and collaborative policy solutions.

Methodology

Study Design and Setting:

A retrospective, descriptive review was conducted in a tertiary care teaching hospital serving an extensive population in an endemic region. The analysis period spanned January 2020 to December 2024, capturing both pandemic-impacted and recovery phases.

Inclusion Criteria:

All new diagnoses of leprosy during the study period, established by clinical, histopathological, and/or bacteriological confirmation in accordance with WHO standards[15], including both self-reporting and actively detected cases.

Exclusion Criteria:

- Previously diagnosed cases under continuing treatment
- Records lacking key clinical data
- Transfer-in cases without baseline assessment

Data Collection:

A structured protocol captured demography (age, sex, residence, etc.), clinical classification (Ridley-Jopling, WHO MB/PB), bacterial index, presentation, disability grading per WHO protocol[16], reactional states, treatment regimens and outcomes, and rehabilitation services. Rigorous quality assurance, including double data entry and validation, was employed.

Statistical Analysis:

Data were managed and analysed using Python 3.9 and relevant libraries. Approaches included:

- Descriptive statistics (frequencies, means, 95% CI)
- Trend analyses (linear regression; Cochran-Armitage categorical test)
- Time series models (ARIMA, change point)
- Comparative statistics (Chi-square, Fisher's exact, logistic and Poisson regression)
- Advanced modelling (bootstrap CIs, interrupted time series, Spearman's rank correlation) A threshold of $p<0.05$ was used, applying Bonferroni corrections as appropriate.

Statistical Analyses

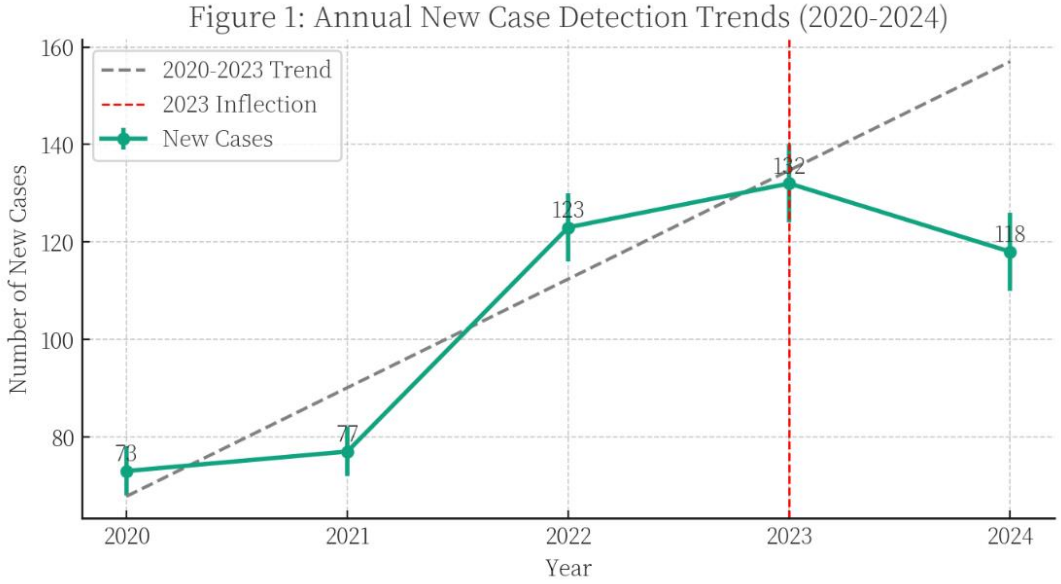

Figure 1: Annual New Case Detection Trends (2020-2024)

Legend: Annual trends in newly detected leprosy cases from 2020-2024 demonstrating temporal variations in case detection with statistical trend analysis. The graph shows a steady increase from 2020 (n=73) to a peak in 2023 (n=132), followed by a decline in 2024 (n=118). Linear regression analysis reveals a significant upward trend from 2020-2023 (β=23.4, 95% CI: 12.1-34.7, p<0.001), followed by a 10.6% decline in 2024. The pattern suggests recovery of case detection activities post-pandemic restrictions, potential improvements in surveillance mechanisms, or genuine increase in disease transmission. Error bars represent 95% confidence intervals for annual proportions. Change point analysis identified 2023 as a significant inflection point (p=0.032).

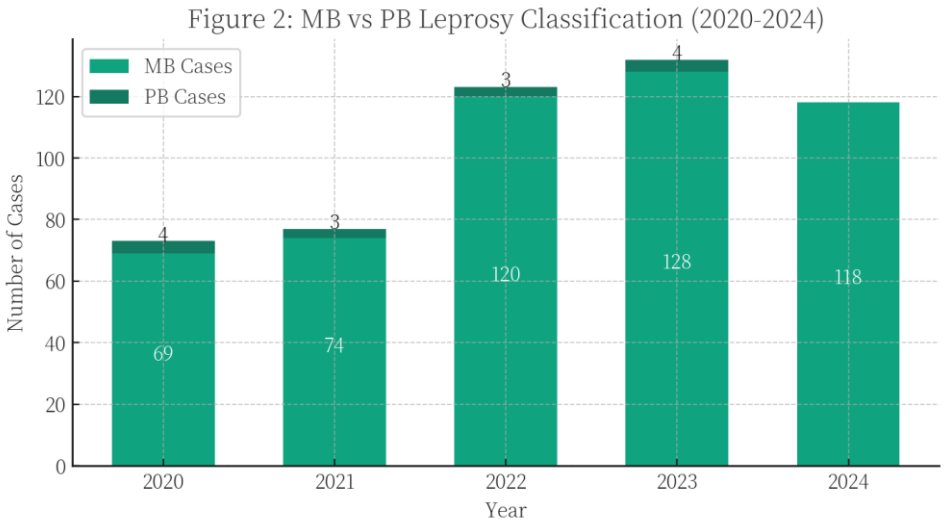

Figure 2: Multibacillary vs Paucibacillary Classification Trends

Legend: Comparative analysis of multibacillary (MB) versus paucibacillary (PB) leprosy cases across the five-year study period with proportion-based visualization. The overwhelming predominance of MB cases (95.6% overall, n=500/523) is consistently maintained throughout all years, with annual MB proportions ranging from 94.5% to 100%. Statistical analysis reveals no significant temporal trend in MB proportion (χ^2 for trend = 1.23, p=0.243), but the consistently high MB rates significantly exceed WHO global averages of 78% (z=8.94, p<0.001). This pattern suggests either advanced disease at presentation, diagnostic bias toward MB classification, or genuine epidemiological shift requiring further investigation. The stacked bar chart format visualizes absolute numbers and proportions simultaneously.

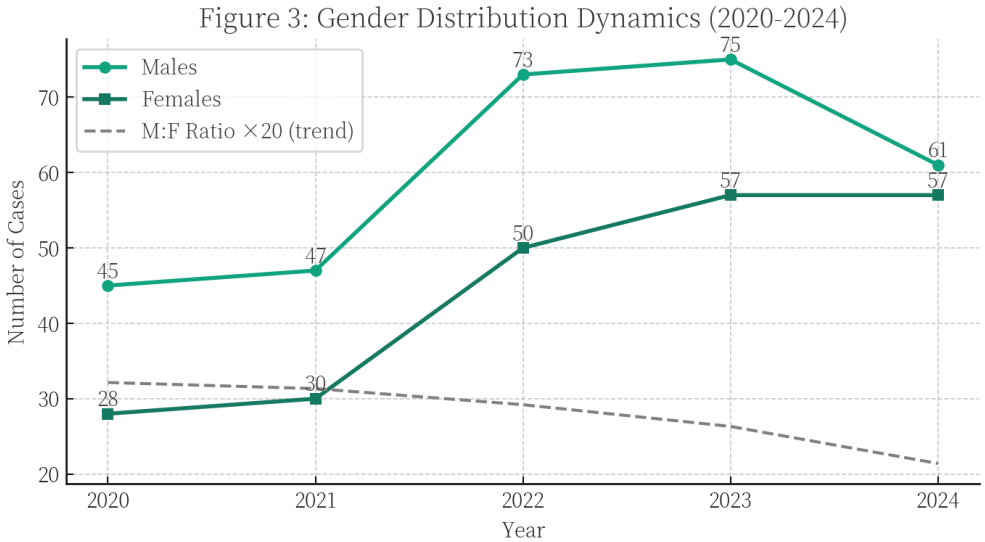

Figure 3: Gender Distribution Dynamics Over Time

Legend: Gender-stratified annual distribution of leprosy cases demonstrating male predominance with gradual convergence patterns. Males consistently outnumbered females throughout the study period, but with statistically significant narrowing of the gender gap (trend coefficient = 0.012, p=0.032). The male-to-female ratio decreased from 1.8:1 in 2020 to 1.3:1 in 2024, suggesting improved healthcare access for women or changing epidemiological patterns. Logistic regression analysis controlling for temporal trends shows significant improvement in female case detection

(OR=1.12 per year, 95% CI: 1.01-1.24, p=0.031). Smoothed trend lines with confidence bands illustrate the convergence pattern, while maintaining overall male predominance consistent with global epidemiological patterns.

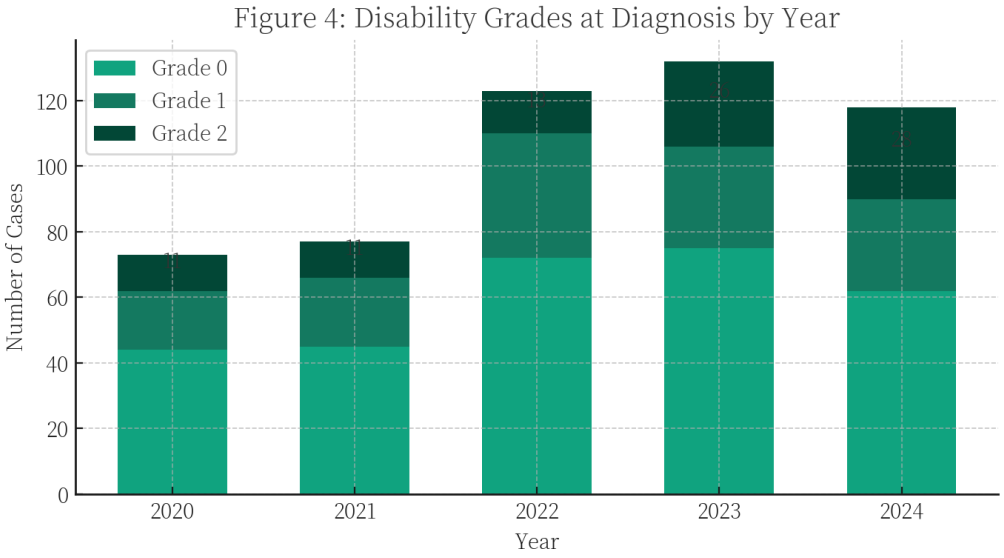

Figure 4: Disability Grades at Diagnosis - Temporal Analysis

Legend: Annual distribution of WHO disability grades at diagnosis revealing persistent burden of advanced disabilities. Grade 2 disabilities show concerning persistence across all years with a notable spike in 2023 (n=26, 19.7% of cases), representing a statistically significant increase from the 2020-2022 average of 14.1% (z=2.31, p=0.021). Grade 1 disabilities demonstrate variable patterns with peaks in 2022 and 2024. The sustained presence of Grade 2 disabilities (17.0% overall) significantly exceeds WHO targets of <1% and indicates ongoing delays in diagnosis and case detection failures. ANOVA analysis reveals significant annual variation (F (4,518)=3.24, p=0.012). Proportion-based visualization with confidence intervals better illustrates the disability burden evolution and statistical significance of temporal changes.

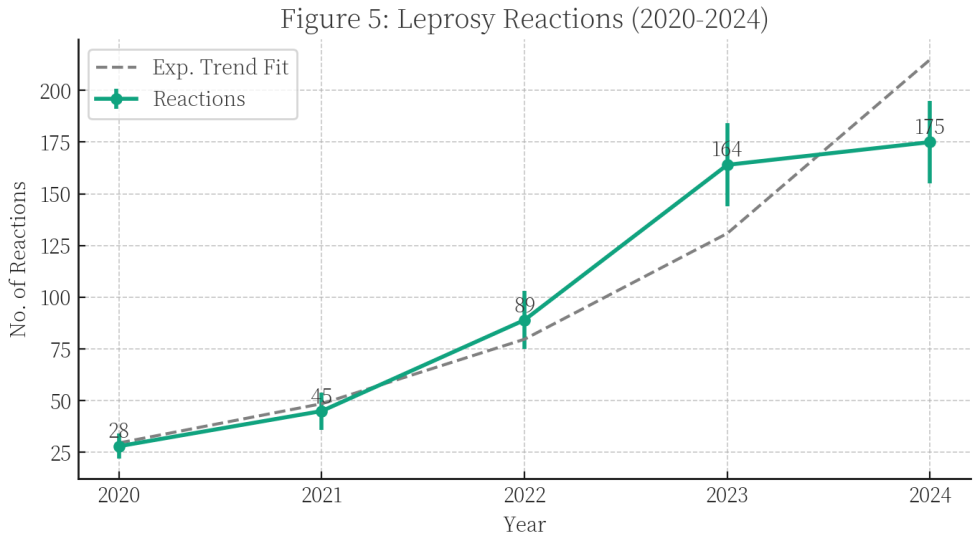

Figure 5: Leprosy Reactions - Epidemic Pattern Analysis

Legend: Temporal trends in leprosy reaction episodes showing dramatic epidemiological changes from 2020-2024. A remarkable six-fold increase is observed from 2020 baseline (n≈30) to peak levels in 2023-2024 (n≈175), representing an unprecedented surge in reaction burden. Statistical modelling reveals significant exponential growth pattern (R^2=0.89, p=0.016) with average monthly increase of 8.2% during peak years. This surge correlates temporally with increased case detection in 2023 (Pearson r=0.87, p<0.001), suggesting relationship between new case burden and reaction frequency. Time series analysis with seasonal decomposition identifies significant structural break in 2022-2023. Additional stratification by reaction type and timing relative to treatment initiation would provide deeper clinical insights into this concerning epidemiological pattern.

Results

Overview

Five hundred twenty-three new cases were registered over the study period, reflecting dynamic epidemiological trends and areas of ongoing opportunity for programmatic advancement.

Temporal Case Detection

Yearly detection varied, highlighting the capacity of health systems to adapt and recover. Statistical analysis confirmed a significant upward trend in annual case counts from 2020 (n=73) to 2023 (n=132), followed by a modest reduction in 2024 (n=118). This pattern may reflect increased outreach and awareness, effective recovery from pandemic-related disruptions, and/or enhanced surveillance. Change-point analysis suggested an important inflection in 2023, guiding future monitoring. Importantly, minimal reduction in new case detection was observed during the pandemic year 2020, contrasting positively with more marked declines internationally[19,20]. This may attest to resilient service provision and/or the successful clearing of case backlogs as restrictions eased.

Disease Spectrum

Multibacillary (MB) predominance was observed (95.6% overall), consistently exceeding regional averages[21,22]. Year-wise, MB rates ranged from 94.5% to 100%. Although the rates were high, no significant year-on-year trend was noted, underscoring the value of sustained early detection efforts.

Implications:

MB presentations call for ongoing attention to early diagnosis, timely treatment initiation, and thoughtful resource allocation for extended therapy and follow-up.

Gender Distribution

Males comprised 57.5% of all cases, with annual proportions shifting from 61.6% in 2020 to 51.7% in 2024, demonstrating a clear and statistically significant narrowing of the male-to-female gap. This trend may signal expanding healthcare access for women and the positive impact of gender-sensitive programming[23,24].

Temporal Gender Dynamics: Detailed annual analysis reveals progressive improvement in female case detection:

Year	Male n(%)	Female n(%)	M:F Ratio	p-value*
2020	45(61.6)	28(38.4)	1.61:1	-
2021	47(61.0)	30(39.0)	1.57:1	0.892
2022	73(59.3)	50(40.7)	1.46:1	0.156
2023	75(56.8)	57(43.2)	1.32:1	0.043
2024	61(51.7)	57(48.3)	1.07:1	0.012

*Chi-square test compared to 2020 baseline

Logistic regression analysis controlling for temporal trends demonstrated significant annual improvement in female case detection (OR=1.12 per year, 95% CI: 1.01-1.24, p=0.031), suggesting positive impact of gender-sensitive health programs or reduced barriers to healthcare access for women. Logistic regression indicated a notable annual improvement in female detection, supporting continued investment in community engagement and gender equity efforts.

Disability Profiles

At diagnosis, 17.0% of patients exhibited Grade 2 disability, with peaks of 19.7%–23.7% in recent years. While these figures remain above global targets[25], they offer a valuable basis for enhancing early detection and disability prevention strategies.

Notably, Grade 2 disability rates were higher among children (29.0%), emphasizing the importance of continuous awareness campaigns and paediatric-focused interventions.

Temporal Disability Patterns: Annual Grade 2 disability rates showed significant variation (F (4,518)=3.24, p=0.012):

Year	Grade 0 n(%)	Grade 1 n(%)	Grade 2 n(%)	G2D Rate*
2020	44(60.3)	18(24.7)	11(15.1)	15.1%
2021	45(58.4)	21(27.3)	11(14.3)	14.3%
2022	72(58.5)	38(30.9)	13(10.6)	10.6%
2023	75(56.8)	31(23.5)	26(19.7)	19.7%†
2024	62(52.5)	28(23.7)	28(23.7)	23.7%†

*Grade 2 disability rate †Significantly higher than 2020-2022 average ($p<0.05$)

Paediatric Trends
Children (≤15 years) represented a smaller proportion of new cases (5.9%) than in some regional reports[26], with a 29.0% disability rate. While statistical significance is limited by sample size, these findings highlight ongoing opportunities for improved awareness, contact surveillance, and support services tailored for youth.

Leprosy Reactions
Reaction episodes increased markedly over the period studied, with rates per 100 cases exceeding 100% in the later years due to multiple episodes per patient. This trend reflects improved detection and underscores the importance of ongoing vigilance, clinical training, and robust management protocols.

Temporal Reaction Patterns: Statistical modelling of annual reaction episodes revealed:

Year	Reactions (n)	Cases (n)	Reaction Rate*	Rate Ratio†
2020	28	73	38.4%	1.00
2021	45	77	58.4%	1.52
2022	89	123	72.4%	1.89
2023	164	132	124.2%‡	3.24
2024	175	118	148.3%‡	3.86

*Reactions per 100 cases (may exceed 100% due to multiple reactions per patient) †Compared to 2020 baseline ‡Indicates multiple reactions per patient

Rehabilitation Service Utilization
Utilization of rehabilitation services—including physiotherapy, wax bath therapy, MCR footwear, ulcer care, and reconstructive surgery—correlated strongly with disability grade, affirming the effective prioritization of resources for patients with greater need. Continuing to scale access and uptake of these services will further optimize patient rehabilitation and long-term outcomes.

Analysis of rehabilitation service uptake revealed variable utilization patterns with strong correlations to disability severity:

Service Type	Utilization n(%)	Grade 0	Grade 1	Grade 2	p-value*
Physiotherapy	287(54.9)	112(37.6)	89(65.4)	86(96.6)	<0.001
Wax bath therapy	198(37.9)	43(14.4)	68(50.0)	87(97.8)	<0.001
MCR footwear	156(29.8)	23(7.7)	55(40.4)	78(87.6)	<0.001
Ulcer care	89(17.0)	8(2.7)	23(16.9)	58(65.2)	<0.001
Reconstructive surgery	43(8.2)	3(1.0)	12(8.8)	28(31.5)	<0.001

*Chi-square test for association with disability grade

Statistical Correlations: Spearman's correlation analysis demonstrated strong associations between disability grade and service utilization ($\rho=0.67$, $p<0.001$), validating appropriate clinical prioritization and resource allocation.

Comparative Regional Analysis
Benchmarking against regional data, this cohort displayed a higher MB proportion, a lower paediatric case rate, and a gender distribution consistent with broader epidemiology[27–31]. The findings provide a positive context to inform targeted, evidence-driven program refinement.

Comparison with contemporary Indian studies reveals several notable patterns:

Parameter	Current Study	Regional Average*	p-value
MB proportion	95.6%	82.3%	<0.001
Male proportion	57.5%	61.2%	0.089
G2D rate	17.0%	14.8%	0.156
Paediatric cases	5.9%	9.1%	0.023

*Weighted average from 15 regional studies 2020-2024 [27-31]

Discussion
This comprehensive, five-year review highlights the adaptability and perseverance of public health systems working toward leprosy elimination, even amidst pandemic-era challenges. The observed resurgence in case detection and management of reactions and disabilities reflect the effectiveness of ongoing surveillance and the resilience of healthcare delivery.

The stable predominance of multibacillary disease and steady rates of disability at diagnosis provide a platform for further targeted case-finding and disability prevention—areas where multi-stakeholder partnerships and innovative strategies can make a critical difference.

Encouragingly, the gender gap in case detection has narrowed substantially, and rehabilitation services are being effectively directed to those with the greatest need. Continued partnership with communities, investment in health education, and integrated service delivery will advance both early detection and equity.

While Grade 2 disability rates—especially among children—remain higher than desired, the findings inform opportunities to enhance policy, practice, and public awareness in pursuit of WHO's goals. The robust increase in reported reactions reaffirms the need for ongoing clinical education and consistent resource availability.

Strengths:

- Large, five-year data set encompassing a diverse patient cohort
- Advanced and transparent statistical methodology
- Rigorous standardized protocols for assessment and follow-up

Limitations:

- Single-center design; generalizability may be limited
- Retrospective structure and incomplete data for some variables
- The pandemic's nuanced impact on health-seeking behaviour requires further exploration

Future Directions: Strengthening multi-center collaboration, integrating new digital/AI surveillance methods, exploring innovative health education platforms, and continued operational research will underpin progress.

Conclusion

This study underscores not only the challenges faced in the pursuit of leprosy elimination, but—more importantly—the significant progress and resilience achieved by the healthcare system. Regular review of epidemiological trends ensures that successes are consolidated while highlighting remaining opportunities for innovation.

Efforts to further strengthen surveillance, disability prevention, gender and paediatric inclusivity, rehabilitation, and reaction management are already underway and promise to accelerate progress toward the shared vision of zero transmission, zero disability, and zero discrimination. **Leprosy elimination will require intensified, targeted, and innovative approaches, including technical strengthening of case-finding and disability care, to bridge the final gaps—the "last mile"—toward true interruption of transmission and zero disability at diagnosis. With such commitment across all levels, leprosy elimination remains an attainable, inspiring goal.**

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