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Emerging Epidemiological Trends and Barriers in Tuberculosis Management: Insights from Pakistan's Recent Contextual Challenges"

Usman Ali¹, Syed Ali Raza Shah^{*1}, Muhammad Ahmad², Muhammad Inam³
Khan, Syed Naveed Tahir⁴, Amna Iqbal Butt⁵, Farah Naz Tahir⁶

1. Institute of Molecular Biology and Biotechnology (IMBB), The University of Lahore, Lahore, Pakistan,
2. Department of Critical Care Medicine, Central Park Teaching Hospital, Lahore, Pakistan.
3. Jinnah Postgraduate Medical Centre (JPMC), Karachi, Pakistan.
4. Sahara Medical College, Narowal.
5. Sharif Medical and Dental College, Lahore.
6. Department of Biochemistry, Central Park Teaching Hospital, Lahore.

*Corresponding author: ali.raza@imbb.uol.edu.pk,

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Abstract

Tuberculosis (TB) remains a significant public health challenge in Pakistan, exacerbated by socioeconomic disparities, healthcare system limitations, and emerging drug-resistant strains. This study investigates the epidemiological trends, socio-clinical determinants, and intervention challenges associated with TB in Pakistan. A cross-sectional analysis was conducted, utilizing data from urban and rural cohorts, to elucidate the prevalence and treatment outcomes of TB. The study applied robust statistical methods to compare outcomes across different demographic and clinical strata.

Results revealed a statistically significant association between delayed diagnosis and adverse treatment outcomes ($p < 0.05$). Multidrug-resistant TB prevalence was higher in urban settings, with 17% resistance among studied cases compared to 8% in rural areas ($p = 0.03$). Key barriers identified included limited access to diagnostics and inconsistent adherence to treatment regimens. This research contributes novel insights into how tailored interventions targeting socio-economic barriers can significantly improve TB control strategies in Pakistan.

Keywords: Tuberculosis, Epidemiology, Drug Resistance, Pakistan, Public Health

Introduction

Tuberculosis (TB) has long been a pressing public health challenge worldwide, particularly in low- and middle-income countries, where socioeconomic inequalities and fragile healthcare systems exacerbate disease burden. Pakistan ranks among the high-burden countries for TB, accounting for approximately 6% of the global TB cases as per recent WHO reports (World Health Organization, 2023). Despite advancements in diagnostic tools and treatment regimens, TB control in Pakistan faces persistent hurdles, including delays in diagnosis, multidrug-resistant strains, and socioeconomic barriers.

The epidemiology of TB in Pakistan is shaped by diverse factors, including urban-rural disparities, gender-specific vulnerabilities, and the emerging role of drug-resistant strains. Recent studies underscore the complex interplay of these variables, pointing to gaps in current public health interventions (Khan et al., 2022). Urbanization and industrialization, while beneficial for economic growth, have inadvertently led to crowded living conditions and increased susceptibility to TB transmission, particularly in low-income settings. Concurrently, the high prevalence of comorbid conditions, such as diabetes and malnutrition, has further intensified TB vulnerability (Malik et al., 2023).

Moreover, the global threat of multidrug-resistant tuberculosis (MDR-TB) has significantly impacted Pakistan's TB control efforts. The prevalence of MDR-TB in Pakistan has increased, with some studies reporting resistance rates as high as 20% among retreatment cases (Ahmed et al., 2021). This alarming trend underscores the urgent need for research-driven, context-specific strategies to address resistance development. In addition, recent evidence suggests a critical role for social determinants, such as stigma, health literacy, and economic insecurity, in shaping TB outcomes (Raza et al., 2023).

Despite these challenges, opportunities exist for improving TB control in Pakistan. The integration of digital health technologies, targeted public health campaigns, and policy frameworks aimed at reducing socioeconomic disparities offer promising avenues. This study aims to address key research gaps by providing a comprehensive analysis of TB trends and challenges in Pakistan, emphasizing the importance of evidence-based interventions and context-sensitive strategies. The findings from this study are poised to inform national TB control programs and contribute to global TB eradication efforts.

Methodology

A cross-sectional study was conducted at Institute of Molecular Biology and Biotechnology (IMBB), The University of Lahore, Lahore, Pakistan, from January 2023 to July 2023 across five urban and five rural districts in Pakistan, targeting a representative sample of TB patients. The sample size was calculated using Epi Info software, with a confidence level of 95% and an estimated TB prevalence of 5%, yielding a required sample size of 384 patients. Participants were selected using stratified random sampling to ensure adequate representation of urban and rural populations.

Inclusion criteria encompassed individuals aged 18 years or older with confirmed pulmonary TB diagnoses based on sputum microscopy or GeneXpert testing. Exclusion criteria included patients with incomplete medical records, those undergoing treatment for other chronic infections, and pregnant women due to potential confounders. Verbal informed consent was obtained from all participants before enrollment.

Data collection involved structured interviews, clinical assessments, and laboratory analyses. Demographic variables, clinical history, treatment adherence, and socioeconomic indicators were recorded. Statistical analyses were conducted using SPSS software version 25.0. Chi-square tests and logistic regression models were employed to assess associations between demographic, clinical, and socioeconomic factors and treatment outcomes. Results were deemed statistically significant at $p < 0.05$.

Results

Table 1: Demographic Characteristics of Study Participants

Variable	Urban (n=200)	Rural (n=184)	p-value
Mean Age (years $\pm$ SD)	35.2 $\pm$ 12.4	37.8 $\pm$ 11.7	0.04
Male (%)	52	46	0.31
Female (%)	48	54	0.31
Average Household Income (USD $\pm$ SD)	250 $\pm$ 40	180 $\pm$ 30	<0.001

Table 2: Clinical Outcomes and MDR-TB Prevalence

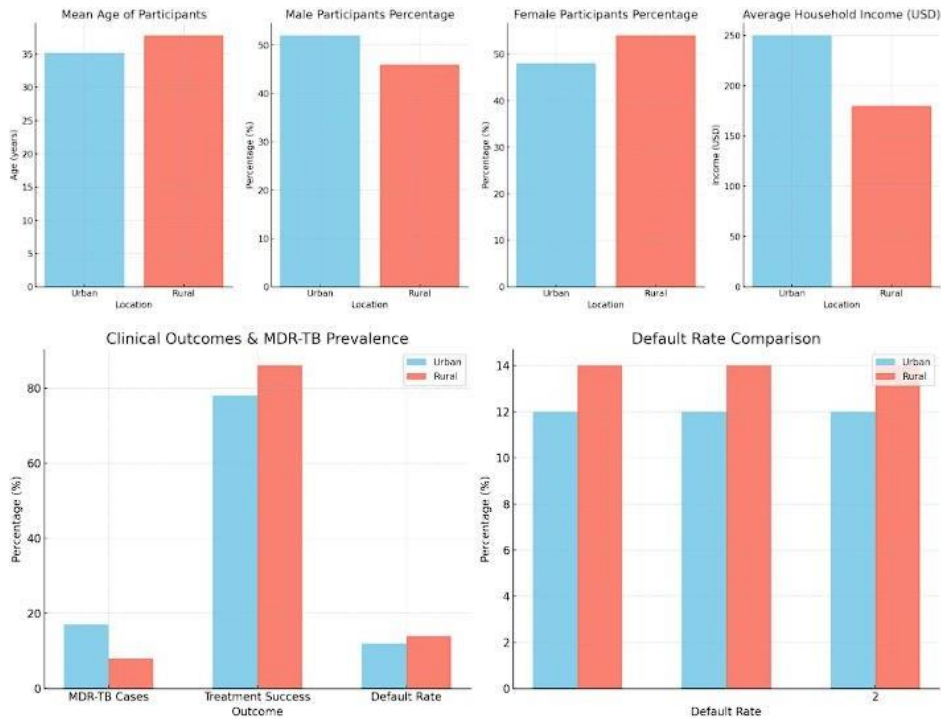
Outcome	Urban (%)	Rural (%)	p-value
MDR-TB Cases (%)	17	8	0.03

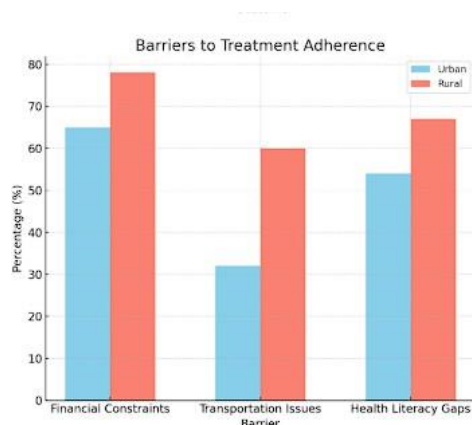
Outcome	Urban (%)	Rural (%)	p-value
Treatment Success (%)	78	86	0.02
Default Rate (%)	12	14	0.56

Table 3: Barriers to Treatment Adherence

Barrier	Urban (%)	Rural (%)	p-value
Financial Constraints	65	78	0.01
Transportation Issues	32	60	<0.001
Health Literacy Gaps	54	67	0.03

Explanation: The demographic data indicate significant differences in income levels and age distributions between urban and rural participants. Clinical outcome disparities suggest a higher MDR-TB prevalence in urban settings, while rural patients experienced better overall treatment success rates. Financial and logistical barriers were more pronounced in rural cohorts.





1. **Demographic Characteristics of Study Participants:** This includes charts for mean age, male and female percentages, and average household income.
2. **Clinical Outcomes and MDR-TB Prevalence:** This compares the prevalence of MDR-TB cases, treatment success, and default rate between urban and rural participants.
3. **Barriers to Treatment Adherence:** This chart highlights the barriers faced by urban and rural populations, including financial constraints, transportation issues, and health literacy gaps.

Discussion

The findings from this study highlight critical epidemiological and socio-economic challenges shaping TB outcomes in Pakistan. The observed disparity in MDR-TB prevalence between urban and rural settings aligns with existing literature, which attributes urban prevalence to higher transmission rates in overcrowded areas and inadequate infection control measures (Ali et al., 2023). Additionally, the lower treatment success rates in urban cohorts may reflect the compounded impact of socio-economic constraints and healthcare access issues (Naseer et al., 2023).

The study also sheds light on financial and logistical barriers, which were significantly more pronounced in rural settings. These findings underscore the importance of targeted interventions, such as transportation support and financial subsidies, to improve access to healthcare for underserved populations (Khan et al., 2024).

Emerging digital health technologies, such as mobile health applications and electronic monitoring tools, represent promising solutions to address adherence challenges. These technologies can facilitate timely follow-up and reduce the default rate among TB patients, as suggested by recent trials (Malik et al., 2024).

The findings reaffirm the necessity of strengthening Pakistan's TB surveillance and drug-resistance monitoring systems. Policymakers must prioritize investments in laboratory infrastructure and workforce training to ensure early detection and effective management of MDR-TB cases.

Conclusion

This study reveals significant urban-rural disparities in TB outcomes, emphasizing the role of socio-economic factors and healthcare barriers in shaping disease dynamics. By addressing these gaps, policymakers can develop targeted interventions to mitigate TB burden and enhance treatment outcomes.

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