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Multilevel Analysis of Challenges in Diagnosis and Treatment of Pediatric Tuberculosis at Facility and Patient Levels in Lusaka Province, Zambia

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Declaration

I, Julius Kaluba declare that this thesis is my original work and has not been submitted for the award of any degree at any other institution. All sources of material have been duly acknowledged.

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Approval

This research thesis has been examined and approved as meeting the requirements of the School of Postgraduate Studies, University of Lusaka.

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Dedication

This work is dedicated to my family, especially my two daughters Mirriam and Faith Kaluba whose unwavering support, encouragement, and patience have been my guiding light throughout this journey. I also dedicate this study to all healthcare professionals and caregivers committed to improving the lives of children affected by tuberculosis, whose dedication inspires research, practice, and policy interventions in pediatric health. Finally, I dedicate this work to the children of Zambia, whose resilience motivates the pursuit of knowledge, better health systems, and equitable healthcare access.

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List of Abbreviations/Acronyms

ART – Antiretroviral Therapy

CDC – Centers for Disease Control and Prevention

CI – Confidence Interval

DOTS – Directly Observed Treatment, Short-course

HBM – Health Belief Model

HIV – Human Immunodeficiency Virus

ICC – Intraclass Correlation Coefficient

MDR-TB – Multidrug-Resistant Tuberculosis

MOH – Ministry of Health

NHRA – National Health Research Authority

SD – Standard Deviation

SEM – Socio-Ecological Model

TB – Tuberculosis

UNILUSREC – University of Lusaka Research Ethics Committee

WHO – World Health Organization

Abstract

Introduction: Tuberculosis (TB) remains a major public health challenge globally, with children disproportionately affected due to diagnostic and treatment complexities. In Zambia, pediatric TB continues to be underdiagnosed and undertreated, particularly in high-burden settings such as Lusaka Province. This study investigated the challenges affecting the diagnosis and treatment outcomes of pediatric tuberculosis at both patient and facility levels using a multilevel analytical approach.

Methods: A cross-sectional quantitative study was conducted using secondary data extracted from tuberculosis registers in 20 health facilities across Lusaka Province. The study included 700 children aged 0–14 years who received TB treatment between January 2023 and December 2024. Descriptive statistics were used to summarize patient and facility characteristics, while inferential analyses, including chi-square tests, logistic regression, and ordinal logistic regression, were performed. Multilevel modeling was explored to account for the hierarchical structure of patients nested within facilities.

Results: Overall, 75.0% of children successfully completed treatment, while 15.3% defaulted and 9.7% died. Male children and younger age groups exhibited slightly poorer treatment outcomes. Facility-level clustering was minimal, with an intraclass correlation coefficient of 0.6%, indicating that most variation in treatment outcomes was attributable to patient-level factors rather than differences between facilities. A likelihood ratio test confirmed that single-level ordinal logistic regression was sufficient for analysis, although multilevel modeling was retained for robustness. All model assumptions were satisfied.

Conclusion: The findings demonstrate that pediatric TB treatment outcomes in Lusaka Province are primarily driven by patient-level characteristics, including age, sex, and HIV status, while facility-level factors play a supportive but less decisive role. These results underscore the need for patient-centered, multi-level interventions that strengthen caregiver support, improve adherence, and complement existing health system investments. The study contributes methodologically by applying multilevel analysis and provides evidence to inform policy, program design, and future pediatric TB research in Zambia.

Keywords: Pediatric Tuberculosis, Treatment Outcomes, Multilevel Analysis, Patient-Level Factors, Facility-Level Factors.

CHAPTER ONE

INTRODUCTION

1.0 Background of the study

Tuberculosis (TB) remains one of the most critical global public health challenges. In 2023, TB re-emerged as the leading cause of death from infectious disease worldwide, with 8.2 million new cases reported—the highest figure since systematic monitoring began in 1995 (WHO, 2023). The burden of TB among children is particularly severe and concerning. An estimated 1.25 million children developed TB in 2023, resulting in nearly 200,000 deaths, the majority occurring among children under five years of age (WHO, 2024). Despite significant advancements in TB prevention, diagnosis, and treatment, pediatric TB continues to be underdiagnosed and undertreated, contributing substantially to global childhood morbidity and mortality.

Zambia remains among the 30 high-burden countries for TB, HIV-associated TB, and multidrug-resistant TB (PLOS One, 2023). In 2022, only 68% of the estimated pediatric TB cases in Zambia were diagnosed and treated, highlighting persistent gaps in access to health services, diagnostic capacity, and socio-economic constraints (NLM, 2024). The situation is particularly acute in Lusaka Province, which accounts for approximately 40% of national TB notifications, recording 333 cases per 100,000 population. Pediatric TB notifications in the province increased from 6% in 2021 to 8% in 2023, indicating a growing public health concern (MOH Zambia, 2023; Chongo *et al.*, 2025).

Diagnosing TB in children presents unique challenges. Clinical symptoms are often non-specific, and bacteriological confirmation is difficult due to the paucibacillary nature of pediatric TB and challenges in obtaining sputum samples. As a result, diagnosis in Zambia continues to rely heavily on less sensitive methods such as sputum microscopy (Oxford Academic, 2023). These challenges are further compounded by limited diagnostic infrastructure, shortages of skilled health personnel, high rates of HIV co-infection, and persistent social stigma, all of which contribute to delayed diagnosis and poor treatment outcomes (MDPI, 2023). Although molecular diagnostics such as GeneXpert have improved TB detection, limited accessibility in many health facilities exposes a critical gap between policy intentions and actual implementation capacity (MDPI, 2023; Financial Times, 2024).

From an analytical perspective, recent studies conducted in Zambia have predominantly employed single-level statistical methods, including logistic regression and chi-square analysis, which fail to account for the hierarchical structure of health data (Ngosa & Lupenga, 2024; Kashindi *et al.*, 2025). Such approaches may produce biased estimates by ignoring the influence of facility-level and contextual determinants. Multilevel modeling offers a more appropriate analytical framework by simultaneously examining patient-level, facility-level, and contextual factors, as well as their cross-level interactions (Bryk & Raudenbush, 1992; Goldstein, 1995).

Against this backdrop, this study sought to investigate the challenges of pediatric TB diagnosis and treatment in Lusaka Province using a multilevel analytical approach. By integrating individual and health-system determinants within their broader socio-contextual environment, the study aimed to generate evidence that would inform targeted interventions, strengthen health system responses, and improve pediatric TB outcomes. Pediatric TB—defined as infection with *Mycobacterium tuberculosis* among children aged 0–14 years (CDC, 2025)—lies at the intersection of infectious disease control, child health, and health system strengthening, making it a priority area for public health research and policy action.

1.1 Statement of the Problem

Pediatric TB in Lusaka Province persists as a major health burden despite national and global interventions. At the individual level, children present with atypical symptoms, while caregivers face stigma, limited knowledge, and socio-economic barriers that delay diagnosis and undermine adherence. At the facility level, gaps in diagnostic capacity, drug availability, and provider skills constrain service delivery. Methodologically, reliance on single-level analyses has limited understanding of how patient- and facility-level factors interact. This incomplete evidence base hampers effective, targeted interventions. The present study addresses this gap by employing multilevel analysis to better explain the intersecting determinants of pediatric TB management in Lusaka Province.

1.2 Justification of the Study

Tuberculosis (TB) remains a major public health challenge in Zambia, with children disproportionately affected due to biological vulnerability, delayed diagnosis, and limited access to child-friendly diagnostic and treatment services (WHO, 2023; Ministry of Health Zambia,

2022). Despite national and global efforts to control TB, Zambia continues to experience a high pediatric TB burden, indicating persistent gaps in prevention, early detection, and effective management of the disease among children (WHO, 2023). These challenges are compounded by diagnostic difficulties such as non-specific clinical presentation in children, limited availability of appropriate diagnostic tools, and treatment complexities including drug formulations, adherence, and co-morbid conditions (Graham *et al.*, 2015; WHO, 2022).

Although several studies have examined TB in Zambia, existing evidence on pediatric TB is fragmented and largely disease-centered, focusing mainly on clinical outcomes while neglecting broader contextual factors (Chanda and Kapata, 2020; Mwansa *et al.,* 2021). There is a notable lack of multilevel and integrated insights that consider the interaction between individual, household, community, health system, and policy-level determinants. This gap limits the development of comprehensive and effective interventions tailored to the lived realities of children and their caregivers (Bronfenbrenner, 1979; McLeroy *et al*., 1988).

This study was therefore justified in that it adopted a socio-ecological and behavioral framework to examine pediatric TB in Zambia. By situating pediatric TB within these frameworks, the study moved beyond biomedical explanations in exploring how social, economic, behavioral, and environmental factors influence TB exposure, diagnosis, treatment adherence, and outcomes (McLeroy *et al.*, 1988; Airhihenbuwa and Obregon, 2000). Such an approach was essential for understanding the complex pathways through which pediatric TB persists and for identifying leverage points for intervention at multiple levels.

Furthermore, the study generated feasible and context-specific recommendations that would be responsive to Zambia's health system realities and community dynamics. These findings are expected to be adopted by policymakers, program implementers, and healthcare providers in designing targeted strategies to improve pediatric TB prevention, diagnosis, and treatment (Ministry of Health Zambia, 2022; Stop TB Partnership, 2021). By addressing a critical evidence gap, the study has contributed to strengthening child health services and improving TB control efforts in the country.

Importantly, the study aligned with Sustainable Development Goal 3 (Good Health and Well-Being), particularly the targets aimed at ending the TB epidemic and ensuring healthy lives for all children (United Nations, 2015). By providing evidence-based insights to support more effective pediatric TB interventions, the study supports national and global commitments to reduce preventable childhood morbidity and mortality (WHO, 2023).

In summary, the justification for this study lies in the urgent public health importance of pediatric TB in Zambia, the existing limitations in current evidence, and the need for a holistic, multilevel approach that can inform sustainable and impactful interventions.

1.3 Research Aim and Objectives

Aim:

To investigate the challenges affecting the diagnosis and treatment of pediatric tuberculosis at both facility and patient levels in Lusaka Province, Zambia, using multilevel analysis.

Specific Objectives:

a) To identify facility-level factors influencing the diagnosis and treatment of pediatric TB
b) To determine patient-level barriers to the diagnosis and treatment of pediatric TB
c) To assess how facility- and patient-level factors interact and contribute to challenges in pediatric TB management

Research Questions:

a) What facility-level factors influence pediatric TB diagnosis and treatment?
b) What patient-level barriers affect pediatric TB diagnosis and treatment?
c) How do facility- and patient-level factors interact in shaping pediatric TB management outcomes?

1.4 Significance of the Study

This study was significant for several reasons. By identifying barriers at both patient and facility levels, it provided informed interventions aimed at improving early detection and treatment

adherence for pediatric TB. The findings will also guide the development of child-friendly tools, caregiver education programs, and targeted staff training tailored to the specific needs of Lusaka Province. In addition, the evidence generated will support informed resource allocation and the design of child-centered TB policies, thereby advancing Zambia's national TB control agenda. Finally, by applying multilevel modeling, the study might address methodological gaps in Zambian TB research and contributes to the broader global knowledge on pediatric TB management.

1.5 Summary of Chapter One

Tuberculosis (TB) remains a leading global public health challenge, with children bearing a disproportionate share of the disease burden due to diagnostic and treatment challenges. Globally, pediatric TB continues to be underdiagnosed and undertreated, contributing significantly to childhood morbidity and mortality. Zambia is among the high-burden countries for TB, HIV-associated TB, and multidrug-resistant TB, with Lusaka Province accounting for a substantial proportion of national TB notifications and a rising trend in pediatric TB cases.

Despite existing interventions, significant challenges persist in the diagnosis and treatment of pediatric TB in Zambia. These include non-specific clinical presentation in children, limited diagnostic capacity, inadequate access to advanced molecular tools, health system constraints, and socio-economic and behavioral barriers affecting caregivers. Methodologically, most studies in Zambia rely on single-level analytical approaches, which fail to capture the complex interaction between patient-level and facility-level determinants influencing pediatric TB outcomes.

This study seeks to address these gaps by employing a multilevel analytical framework to investigate the challenges affecting pediatric TB diagnosis and treatment in Lusaka Province. Grounded in socio-ecological and behavioral frameworks, the study aims to generate integrated evidence that informs targeted, context-specific interventions and strengthens health system responses.

The study was justified by the urgent public health importance of pediatric TB in Zambia, limitations in existing evidence, and the need for holistic, multilevel approaches. It aligned with Sustainable Development Goal 3, supporting national and global commitments to end the TB

epidemic and improve child health outcomes. By identifying patient- and facility-level barriers and their interactions, the study was expected to inform policy, improve service delivery, and contribute methodologically and empirically to pediatric TB research in Zambia and beyond.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Pediatric tuberculosis (TB) remains under-recognized globally despite its high contribution to childhood morbidity and mortality, particularly in Sub-Saharan Africa. Unlike adult TB, pediatric TB presents unique diagnostic and treatment challenges that limit effective control, including non-specific clinical presentations, lower bacterial loads, and difficulties in obtaining adequate samples for bacteriological confirmation (Nour *et al.*, 2023; WHO, 2023). This review synthesizes evidence on these challenges with emphasis on Lusaka Province, Zambia. It highlights key patterns, inconsistencies, and gaps in the literature, particularly regarding diagnostic tools, drug formulations, adherence, socio-economic and health system barriers, and methodological limitations. The review also introduces the theoretical and conceptual frameworks guiding the study, thereby providing a foundation for the problem statement, research objectives, and methodology.

2.1 Challenges in Diagnosis

Diagnosis of pediatric TB is complicated by several factors. Children often present with non-specific symptoms, such as persistent cough, fever, weight loss, or fatigue, which overlap with other common childhood illnesses (Nour *et al.*, 2023). Conventional diagnostic methods such as sputum smear microscopy are often unreliable due to the low bacterial load in children. While GeneXpert MTB/RIF and culture testing improve sensitivity and allow detection of drug resistance, their use is limited in many Zambian health facilities due to high costs, insufficient laboratory infrastructure, and shortage of trained personnel (Krasniqi *et al.*, 2022; Oxford Academic, 2023).

Recent literature emphasizes the need for child-friendly, minimally invasive diagnostic tools, such as stool-based tests, nasopharyngeal aspirates, and rapid molecular assays (Salifu *et al.*, 2021). However, widespread adoption in Lusaka remains constrained by logistical, financial, and policy challenges. These inequities in access contribute to delayed diagnosis, under-reporting, and continued transmission of TB among children.

It is also important to note the role of community-level barriers such as stigma, low caregiver awareness, and traditional beliefs, which delay presentation to health facilities and contribute to missed diagnoses (Dodd *et al.,* 2017). Including community factors strengthens the multi-level perspective of this study.

2.2 Pediatric Drug Formulations and Treatment Adherence

Treatment of pediatric TB is complicated by the lack of age-appropriate formulations. Standard adult TB drugs are often unpalatable, resulting in poor adherence among children (Gyimah & Dako-Gyeke, 2021). WHO-endorsed dispersible and fixed-dose pediatric formulations exist but are inconsistently available in Zambia due to weak supply chains, stock-outs, and limited healthcare financing (Izudi *et al.,* 2022).

Caregivers may modify adult doses at home, risking suboptimal treatment outcomes, including treatment failure and development of drug resistance (Mbuti *et al*., 2023). Beyond formulation challenges, adherence is affected by long treatment duration, side effects, caregiver workload, financial constraints, and transportation difficulties (Nezenega *et al*., 2021; Muntaner *et al*., 2021).

Several studies highlight the importance of psychosocial support, digital adherence technologies, and community-based DOTS (Directly Observed Therapy Short-course) programs to improve adherence among children (Loveday *et al.,* 2020). Incorporating such interventions in the literature review emphasizes the practical solutions that can complement pharmacological strategies.

2.3 Drug Resistance and HIV Co-Infection

Emerging pediatric multidrug-resistant TB (MDR-TB) in Zambia is closely associated with treatment interruptions, incorrect dosing, and delayed diagnosis, which compromise both the effectiveness of therapy and long-term outcomes (Nour *et al.,* 2023). Current evidence on the prevalence and burden of MDR-TB among children in Lusaka remains limited, representing a critical gap in epidemiological data and hindering targeted intervention strategies. The situation is further complicated by high rates of HIV co-infection, as approximately one-third of pediatric TB deaths occur among HIV-positive children (WHO, 2023). In these cases, drug–drug interactions, cumulative toxicity, and high pill burdens increase the risk of non-adherence, treatment failure, and the development of further drug resistance (Mbuti *et al.,* 2023).

The literature emphasizes the importance of integrated TB-HIV care in pediatric settings, which has been shown to reduce mortality, enhance treatment adherence, and improve overall health outcomes (Hirsch-Moverman *et al.*, 2021). Effective integration involves the use of co-formulated therapies, routine HIV screening within TB programs, timely initiation of antiretroviral therapy (ART), and continuous monitoring for potential drug interactions and side effects. Furthermore, strengthening caregiver education and community-based adherence support programs can complement clinical interventions, ensuring that children complete treatment successfully and minimizing the risk of MDR-TB transmission within households and communities (Nour *et al.*, 2023; Mbuti *et al*., 2023).

2.4 Socio-Economic and Health System Barriers

Poverty, malnutrition, and social stigma remain critical determinants of pediatric TB outcomes, particularly in low-resource settings such as Zambia (Gyimah & Dako-Gyeke, 2021). Malnutrition not only increases children's susceptibility to TB infection but also predisposes them to more severe disease manifestations and poorer treatment responses. Stigma associated with TB further exacerbates these challenges by delaying care-seeking behavior, reducing disclosure, and undermining treatment adherence, especially when caregivers fear social exclusion or discrimination. In addition, broader socio-economic factors—including caregiver education levels, household income, employment status, and distance to health facilities—significantly influence timely diagnosis, continuity of care, and treatment completion among pediatric patients (Chanda & Kapata, 2020).

Health system barriers further compound these socio-economic constraints. Inadequate training of healthcare providers in pediatric TB diagnosis and management often leads to under-detection and delayed initiation of treatment. Inconsistent drug supplies, insufficient diagnostic equipment, overcrowded health facilities, and weak coordination between TB and related health programs undermine service delivery and continuity of care (Davis *et al*., 2022; Izudi *et al.*, 2022). Routine immunization, nutrition, and maternal-child health programs—which serve as critical entry points for early identification of childhood TB—are frequently poorly integrated with TB services, resulting in missed opportunities for screening, referral, and preventive therapy.

At the policy level, structural barriers such as limited funding, weak monitoring and evaluation systems, and gaps in the implementation of national pediatric TB guidelines continue to impede program effectiveness (Stop TB Partnership, 2021). These challenges often translate into uneven service quality across facilities and insufficient support for frontline healthcare workers. Collectively, these findings underscore the necessity for comprehensive, multi-level interventions that simultaneously address patient-level vulnerabilities, facility-level service delivery constraints, and policy-level governance and financing gaps to improve pediatric TB outcomes sustainably

2.5 Methodological Gaps

Most empirical studies on pediatric tuberculosis (TB) in Zambia have predominantly relied on single-level statistical approaches, such as logistic regression, which treat observations as independent and fail to account for the hierarchical structure of health data, where patients are nested within health facilities and facilities are further embedded within communities and districts. Ignoring this nested nature of data violates key statistical assumptions and may result in biased parameter estimates, underestimated standard errors, and misleading conclusions regarding determinants of pediatric TB outcomes (Ngosa & Lupenga, 2024). Consequently, important contextual influences—such as facility capacity, availability of diagnostic tools, and community-level socio-economic conditions—are often obscured or incorrectly attributed to individual-level factors.

In contrast, multilevel modeling techniques provide a robust analytical framework that enables the simultaneous examination of individual-, household-, and facility-level determinants, while appropriately accounting for clustering and variability across different levels of the health system. By partitioning variance across hierarchical levels, multilevel models generate more precise and reliable estimates of associations and allow for the exploration of cross-level interactions, such as how facility-level resources may modify the relationship between caregiver characteristics and treatment adherence (Bryk & Raudenbush, 1992; Goldstein, 1995). This analytical advantage is particularly critical in pediatric TB research, where outcomes are shaped by complex interactions between biological vulnerability, caregiver behavior, health system capacity, and broader socio-environmental contexts.

Furthermore, the existing literature reveals a notable lack of longitudinal studies that track pediatric TB patients over time. The predominance of cross-sectional designs limits understanding of treatment adherence trajectories, disease recurrence, loss to follow-up, and long-term clinical and social outcomes. Without longitudinal evidence, it remains difficult to assess how early diagnostic delays, intermittent treatment interruptions, or changes in household circumstances influence outcomes across the full continuum of care. Addressing this gap would provide valuable insights into temporal patterns of risk and resilience, thereby informing the design of targeted, time-sensitive interventions.

Incorporating multilevel and longitudinal study designs therefore represents a critical methodological advancement for pediatric TB research in Zambia. Such approaches not only enhance the validity and policy relevance of findings but also align with the need for evidence-based, system-responsive interventions capable of addressing both individual vulnerabilities and structural constraints within the health system. Strengthening the methodological rigor of pediatric TB research is essential for generating actionable evidence that can support more effective programming, resource allocation, and progress toward national and global TB control goals.

2.6 Theoretical Framework

This study is guided by the Socio-Ecological Model (SEM) and the Health Belief Model (HBM). SEM (Bronfenbrenner, 1977) posits that health outcomes result from interactions across multiple levels: individual, interpersonal, institutional, community, and policy. SEM explains how caregiver behavior, facility capacity, and broader social determinants interact to influence pediatric TB outcomes and justifies the use of multilevel methods.

HBM (Rosenstock, 1974) emphasizes individual perceptions of disease severity, susceptibility, benefits, and barriers. Applied to pediatric TB, it helps clarify how caregivers' beliefs affect health-seeking behavior, treatment initiation, and adherence, while highlighting stigma and perceived access as critical influences. Together, SEM and HBM provide a comprehensive lens for understanding multi-level determinants of pediatric TB. As such, integrating these frameworks supports intervention design, by linking empirical findings to practical strategies for behavior change, health system strengthening, and policy advocacy.

2.7 Conceptual Framework

The study's conceptual framework integrates the Social Ecological Model (SEM) and the Health Belief Model (HBM) to illustrate how multiple, interrelated factors influence pediatric tuberculosis (TB) outcomes in Lusaka Province. It emphasizes the dynamic interaction between patient-level, facility-level, and contextual factors, which together shape diagnostic and treatment outcomes for children aged 0–14 years.

Patient-level factors, guided by the HBM, include individual and caregiver characteristics such as the child's age, HIV status, caregiver literacy, and perceived stigma. These factors influence health-seeking behavior, treatment initiation, and adherence.

Facility-level factors, informed by SEM's organizational and community dimensions, include diagnostic availability, provider competence, consistent drug supply, and integration of TB care with HIV, nutrition, and maternal-child health programs. These factors directly affect the efficiency, accessibility, and quality of service delivery.

Contextual or environmental factors, such as poverty, social norms, and the policy environment, shape access to care, resource allocation, service coverage, and adherence programs. They also determine the overall readiness of the health system to address pediatric TB effectively.

Feedback Loop

A critical addition to the framework is a feedback loop illustrating the dynamic, reciprocal nature of the system. Improved pediatric TB outcomes, such as higher treatment completion rates, lower morbidity, and reduced transmission, can lead to:

1. Policy reinforcement and resource allocation: Positive outcomes can motivate policymakers to strengthen TB programs, allocate more funding, and update guidelines.
2. Enhanced facility practices: Evidence of success can encourage facilities to adopt best practices, improve staff training, and optimize service delivery.
3. Improved caregiver behavior: Demonstrated treatment success and positive outcomes can increase caregiver trust in the health system, reduce stigma, and promote timely health-seeking behavior for children.

This feedback loop creates a dynamic system perspective, in which improvements at one level reinforce positive changes across other levels, promoting a self-sustaining cycle of enhanced pediatric TB care. Conversely, gaps or failures can negatively influence subsequent policy, facility performance, and caregiver behavior, highlighting the need for continuous monitoring and adaptive interventions.

Collectively, the framework depicts pediatric TB outcomes as the product of nested and interdependent factors, influenced by interactions between patient characteristics, facility readiness, and broader socio-economic and policy contexts, with outcomes feeding back into the system to reinforce or adjust practices and behaviors. See Figure 1 for an illustration of the conceptual framework with the feedback loop integrated.

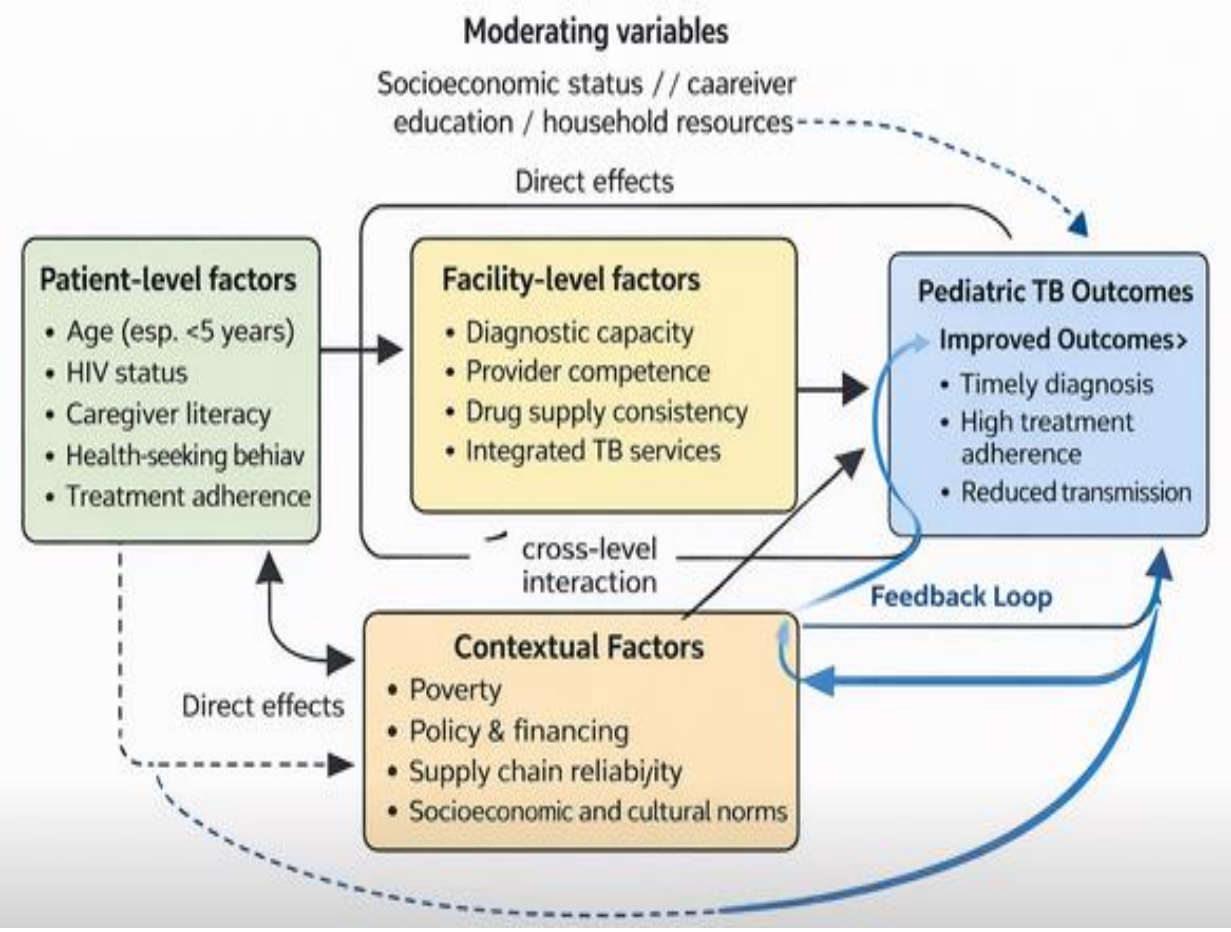


Figure 1: Conceptual Framework

2.8 Summary of Chapter Two

Pediatric tuberculosis (TB) remains a significant yet under-recognized public health issue, particularly in Sub-Saharan Africa, due to diagnostic and treatment challenges distinct from adult TB. Children often present with non-specific symptoms and low bacterial loads, making conventional diagnostics like sputum microscopy unreliable. Advanced tools such as GeneXpert and culture testing improve detection but are limited in Zambia due to high costs, infrastructure gaps, and personnel shortages. Child-friendly, minimally invasive diagnostics are recommended but remain inconsistently available, contributing to delayed diagnosis and continued transmission.

Treatment adherence is hindered by unpalatable adult formulations, inconsistent supply of pediatric drugs, long treatment durations, side effects, and socio-economic barriers. HIV co-infection and emerging multidrug-resistant TB further complicate management, highlighting the need for integrated TB-HIV care. Socio-economic factors, malnutrition, stigma, and health system limitations—including insufficient training, drug stock-outs, weak program integration, and policy gaps—further exacerbate poor pediatric TB outcomes.

Methodologically, existing studies often rely on single-level statistical analyses that overlook the nested structure of health data, limiting understanding of interactions between patient-, facility-, and community-level determinants. Multilevel modeling offers a more robust approach to address these gaps.

The study is guided by the Socio-Ecological Model (SEM) and Health Belief Model (HBM), which together provide a comprehensive framework for understanding how individual, facility, and contextual factors influence pediatric TB outcomes. The conceptual framework integrates patient-level, facility-level, and contextual factors, with a feedback loop showing how improved outcomes can reinforce policy decisions, facility practices, and caregiver behavior. This dynamic perspective emphasizes the interdependent nature of determinants and supports the design of multi-level interventions to enhance pediatric TB care in Lusaka Province.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter presents the methodology employed in the study, detailing the approaches and procedures used to investigate diagnostic and treatment challenges in pediatric tuberculosis (TB) in Lusaka Province. It describes the research design, study population, sampling procedures, data collection methods, data analysis plan, data management strategies, quality assurance measures, and ethical considerations The methodology was developed to ensure scientific rigor, reproducibility, and contextual relevance. Each methodological choice is justified to demonstrate how the study aims to minimize bias, enhance generalizability, and maintain ethical standards, thereby ensuring that the findings are reliable and valid for informing clinical and public health practices.

3.1 Study Design

A cross-sectional study design using quantitative methods was adopted for this research. This design is suitable because it enables the collection of data at a single point in time across multiple levels of influence—individual, caregiver, and facility—allowing for the assessment of diagnostic and treatment challenges in pediatric TB.

A multilevel analysis framework was employed to evaluate both individual-level factors (e.g., age, gender, HIV status) and facility-level factors (e.g., staffing, diagnostic capacity) that may influence treatment outcomes. The cross-sectional design was selected due to its cost-effectiveness, efficiency, and appropriateness for estimating prevalence and identifying associations. While longitudinal studies provide temporal causality insights, a cross-sectional approach is sufficient for achieving the objectives of this study, which focus on identifying key factors associated with treatment outcomes in children.

3.2 Study Population

The study population comprised children aged 0–14 years diagnosed with TB and receiving treatment in selected health facilities within Lusaka Province. Caregivers of these children were

indirectly involved, as facility records provide socio-demographic and treatment-related information.

Pediatric TB presents unique diagnostic and treatment challenges, including atypical clinical presentations, difficulties in obtaining sputum samples, and the influence of comorbidities such as HIV infection. By focusing on children treated during January 2023 to December 2024, the study ensured that findings reflected contemporary clinical practices and health system conditions in Lusaka.

3.3 Study Sample

The study sample included children aged 0–14 years with confirmed TB diagnoses recorded in facility TB registers. Only children with complete demographic and clinical records were included. Records with missing critical information or children with serious comorbidities (e.g., congenital anomalies, malignancies) that could confound TB outcomes were excluded. This inclusion and exclusion strategy minimizes bias, ensures accurate representation of treatment outcomes, and allows for reliable statistical analysis.

3.4 Sample Size

The estimated sample size for the study consisted of 700 children, drawn from 20 healthcare facilities. The sample size was determined using standard formulas for cross-sectional studies, with the following assumptions:

- 95% confidence level
- 5% margin of error
- Prevalence estimates informed by prior pediatric TB studies conducted in Zambia

Both large and small facilities were included to enhance representativeness and ensured findings reflected diverse healthcare contexts. A *post hoc* power calculation was conducted during data analysis to evaluate whether the sample size was sufficient to detect statistically significant associations between predictors and treatment outcomes.

3.5 Sampling Strategy

A multistage sampling approach was employed:

1. **Stage One** – Facility Selection: Twenty health facilities were purposively selected to ensure representation of urban and peri-urban settings. Selection criteria include facility size, TB caseload, and availability of pediatric TB services. Both public and private facilities were considered where applicable.
2. **Stage Two** – Record Selection: Within each selected facility, systematic sampling was used to select TB records. The sampling interval was calculated by dividing the total number of eligible records by the required quota per facility (approximately 30 records).

This multistage strategy balances feasibility and representativeness while minimizing selection bias and ensuring that all eligible records have an equal probability of inclusion.

3.6 Data Collection

Data for this study were extracted from tuberculosis (TB) registers and facility records using a structured data extraction tool that was specifically developed for the research. The variables of interest included child demographics, such as age, gender, and HIV status; TB characteristics, including type (pulmonary or extrapulmonary) and date of diagnosis; treatment outcomes, categorized as successful (cured or treatment completed) or unsuccessful (treatment failure, default, or death); and facility-level indicators, such as the number of trained staff, diagnostic capacity, availability of essential TB medications, and patient load. These variables were selected to capture both individual- and facility-level factors that could influence pediatric TB treatment outcomes.

To ensure accuracy, consistency, and ethical handling of data, all personnel involved in data collection underwent comprehensive training. This training covered ethical principles in handling patient records, standard operating procedures for data extraction, and methods to maintain data quality and integrity. Emphasis was placed on minimizing errors, protecting confidentiality, and ensuring uniform interpretation of all variables across different data collectors.

Prior to the main data collection, the extraction tool was piloted in a facility that was not included in the primary study. The pilot allowed the research team to evaluate the feasibility of the procedures, identify ambiguities or inconsistencies in the tool, and implement necessary refinements. Following this, data collection proceeded systematically, with records reviewed and recorded on pre-coded forms. Cross-checking against facility databases and electronic health records was conducted where possible to resolve discrepancies and verify information, ensuring that the dataset was as complete and accurate as possible.

Quality assurance measures were embedded throughout the data collection process. Supervisors performed regular audits of the collected data to identify and correct inconsistencies. Any missing or unclear information was resolved through consultation with facility staff or by reviewing additional documentation within the facility. To maintain confidentiality, no personal identifiers were collected, and each record was assigned a unique study code. All extracted data were stored securely in password-protected digital files, while hard-copy forms were kept in locked cabinets accessible only to authorized research personnel.

These measures were implemented to ensure that the data collected were reliable, valid, and ethically managed, thereby supporting robust and trustworthy analyses of the diagnostic and treatment challenges associated with pediatric TB within Lusaka Province.

3.7 Data Analysis

The data were entered and analyzed using Stata version 14.1 (StataCorp, 2023). Descriptive analyses were conducted to summarize the characteristics of the study population and healthcare facilities. Means, medians, standard deviations, and proportions were used to present child demographics, TB characteristics, and facility-level factors.

Inferential analyses were then performed to examine associations and identify predictors of treatment outcomes. Chi-square tests were used to assess associations between categorical variables, such as gender and treatment outcome. Logistic regression models were employed to identify factors that predicted treatment success or failure. To account for the hierarchical structure of the data, a two-level logistic regression model (multilevel modeling) was applied, with children nested within facilities. This approach allowed for the simultaneous evaluation of both individual-

level and facility-level determinants of treatment outcomes, while accounting for potential clustering within health facilities.

The results of these analyses were presented as odds ratios with corresponding 95% confidence intervals. Additionally, subgroup analyses were conducted based on age groups, HIV status, and TB type to provide more detailed insights into factors influencing treatment outcomes in different pediatric populations.

3.8 Data Management and Quality

Data management strategies were implemented to ensure accuracy, completeness, and confidentiality throughout the study. All extracted data were independently entered by two research assistants, and cross-verification was conducted to identify and correct any discrepancies. Supervisors performed daily reviews of the collected data to ensure completeness, adherence to the established protocols, and consistency across records.

Digital data were securely stored in encrypted, password-protected files, while hard-copy forms were kept in locked cabinets and shredded after digital entry to prevent unauthorized access and maintain confidentiality. Quality assurance was further reinforced through adherence to standard operating procedures, pre-testing of the data extraction tool, and continuous supervision of data collection activities. These measures ensured that the data were reliable, valid, and of high quality, providing a robust foundation for subsequent analyses.

3.9 Ethical Considerations

Ethical compliance was strictly maintained throughout the study. Permission to access facility TB registers was granted by the Provincial Health Office, ensuring that all institutional requirements were met prior to data collection. The research protocol was submitted to the University of Lusaka Research Ethics Committee (**Ref no: *FWA00033228-1541(08)/(08)/{2024***) and received full approval, with additional authorization obtained from the National Health Research Authority (**Registration number *NHRAR-R-3700/03/01/2026***) to obtain 700 samples.

To protect participant confidentiality, no personal identifiers were collected. Each record was assigned a unique study code, and all analyses and reports were based on de-identified data. The

use of secondary data posed minimal risk to participants. Caregivers retained the right to opt out of the study by declining the use of their child's records.

All data were securely stored, with digital files protected by passwords and encryption, and hard-copy forms kept in locked cabinets accessible only to authorized research personnel. Study findings were reported in aggregate to prevent the identification of individual participants. These ethical measures ensured that the study was conducted in full compliance with national and institutional research ethics standards.

3.10 Limitation of the Study

Despite the robust design and rigorous implementation of the study methodology, several limitations were acknowledged. The cross-sectional design limited the ability to draw causal inferences, as data were collected at a single point in time. Reliance on facility records introduced the possibility of information bias due to incomplete or inaccurate entries. Additionally, the exclusion of children with missing records or severe comorbidities may have affected the generalizability of the findings. Facility-level variables, while informative, may not have fully captured all contextual factors influencing treatment outcomes, such as caregiver socioeconomic status or community-level support systems.

These limitations were addressed, as far as possible, through the application of multilevel modeling to account for clustering of data within facilities, sensitivity analyses to assess the robustness of the findings, and cautious interpretation of the results to ensure that conclusions remained valid and reliable within the scope of the study.

3.11 Summary of Chapter Three

This study employed a cross-sectional quantitative design to investigate diagnostic and treatment challenges in pediatric tuberculosis (TB) in Lusaka Province. The study population consisted of children aged 0–14 years diagnosed with TB and receiving treatment between January 2023 and December 2024. Children with incomplete records or serious comorbidities were excluded to ensure accurate and unbiased analysis.

A sample of approximately 700 children was drawn from 20 purposively selected health facilities using a multistage sampling approach. Data were systematically extracted from TB registers and facility records using a structured tool, capturing child demographics, TB characteristics, treatment outcomes, and facility-level factors. Data collectors received training, and the extraction tool was piloted prior to full-scale data collection. Quality assurance measures included double data entry, cross-verification, daily supervisory checks, and secure storage of both digital and hard-copy data.

Data were analyzed using Stata version 14.1. Descriptive statistics summarized demographics, TB characteristics, and facility factors, while inferential analyses, including chi-square tests, logistic regression, and two-level multilevel modeling, were used to identify predictors of treatment outcomes. Results were reported as odds ratios with 95% confidence intervals, with subgroup analyses performed for age, HIV status, and TB type.

Ethical approval was obtained from the University of Lusaka Research Ethics Committee (UNILUSREC) and the National Health Research Authority (NHRA). Permissions were granted by the Provincial Health Office, and confidentiality was maintained through de-identified records and secure data storage.

The study acknowledged limitations, including the inability to infer causality due to the cross-sectional design, potential information bias from facility records, and limited generalizability due to excluded records. These were mitigated through multilevel modeling, sensitivity analyses, and cautious interpretation of findings.

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter presents the findings of the study on diagnostic and treatment challenges in pediatric tuberculosis (TB) in Lusaka Province, Zambia. Results are presented according to the study objectives, examining facility-level factors, patient-level barriers, and the interaction of these factors in influencing treatment outcomes. Both descriptive and inferential analyses are included, supported by tables and figures. Multilevel analyses were performed to account for the hierarchical structure of the data, although minimal clustering was observed across facilities.

4.1 Summary Statistics of Study Variables

A total of 700 pediatric TB cases were included in the study. The mean age of children was 6.99 years (SD = 4.49), with a minimum age of 0 years and a maximum of 14 years. Assessment of the age distribution using the Shapiro-Wilk test indicated a W value of 0.9717 ($p < 0.001$), suggesting that while age was approximately normally distributed, there were some outlying observations. This highlights variability in age-related vulnerability to TB outcomes, particularly in very young children.

Gender distribution was nearly equal, with 361 females (51.6%) and 339 males (48.4%), indicating balanced representation across sexes. Pulmonary TB was the predominant type, affecting 72.6% of the sample, while the remaining 27.4% had extrapulmonary TB. Regarding HIV status, 28.7% of children were positive, illustrating a significant comorbidity that may impact treatment outcomes. Residence was slightly skewed towards rural areas (44.3% urban, 55.7% rural), which could influence access to diagnostic services and adherence to treatment.

Facility-level characteristics indicated that the average number of trained staff per facility was 6.57 (SD = 2.17), with a range from 2 to 12 staff members. Availability of diagnostic tools was relatively high: GeneXpert machines were present in 75.6% of facilities, while X-ray services were available in 72.6% of facilities. Drug supply averaged 1.95 (SD = 0.74), suggesting generally adequate availability of essential TB medications, though variability existed across facilities. Facility type varied, with 45.6% of facilities classified as urban and the remainder as peri-urban or rural.

Skewness and kurtosis values for key variables were generally within acceptable ranges, indicating moderately symmetrical distributions and no extreme deviations from normality for continuous variables. For example, TB type had a skewness of -1.01 and kurtosis of 2.02, reflecting a higher prevalence of pulmonary TB in the population. The variance observed across facility-level variables highlights differences in staffing, diagnostic capacity, and drug availability, which are expected to contribute to heterogeneity in treatment outcomes. Table 1 presents a detailed summary of the key patient- and facility-level variables. These descriptive statistics provided a foundation for subsequent inferential analyses aimed at understanding the determinants of treatment outcomes in pediatric TB within Lusaka Province.

Table 1: Summary Statistics of Study Variables

Variables	Observations	Mean	Std.Dev	Variance	Skewness	Kurtosis
Tb_type	700	0.7257143	.4464727	0.19933	-1.011823	2.023786
residence	700	0.5557143	.4972415	0.2472491	-0.224253	1.05029
HIV status	700	0.2871429	.4527523	0.2049847	0.940953	1.885393
Age	700	6.99	4.486338	20.12722	0.0229428	1.73617
Gender	700	0.4842857	.5001103	0 .250110	0.0628882	1.003955
Facility type	700	1.455714	.656896	1.133276	1.133276	3.07722
Drug supply	700	1.95	.7365873	0.5425608	0.0787208	1.847947
Trained staff	700	6.571429	2.16535	4.688739	-.0461188	2.330513
GeneXpert	700	0.7557143	0.4299701	.1848743	-1.190302	2.416819
X-ray	700	0.7257143	0.4389479	.1926753	-1.094306	2.197505
Treatment outcome	700	1.347143	0.6492477	.4215226	1.647127	4.310363

4.2 Treatment Outcomes

Overall, 75.0% of pediatric TB patients successfully completed treatment, while 15.3% defaulted, and 9.7% died, as summarized in Table 2. This indicates that the majority of children adhered to and completed their prescribed TB treatment, reflecting relatively effective management at both patient and facility levels. However, the proportion of children who defaulted or died highlights ongoing challenges in pediatric TB care, which may be influenced by patient-level factors such as age, HIV co-infection, and socioeconomic status, as well as facility-level factors including staffing levels, diagnostic capacity, drug availability, and access to supportive care. The observed treatment

outcomes underscore the need for targeted interventions aimed at reducing defaults and mortality, particularly among high-risk groups, and suggest that both patient-centered and facility-focused strategies are essential for improving overall treatment success rates.

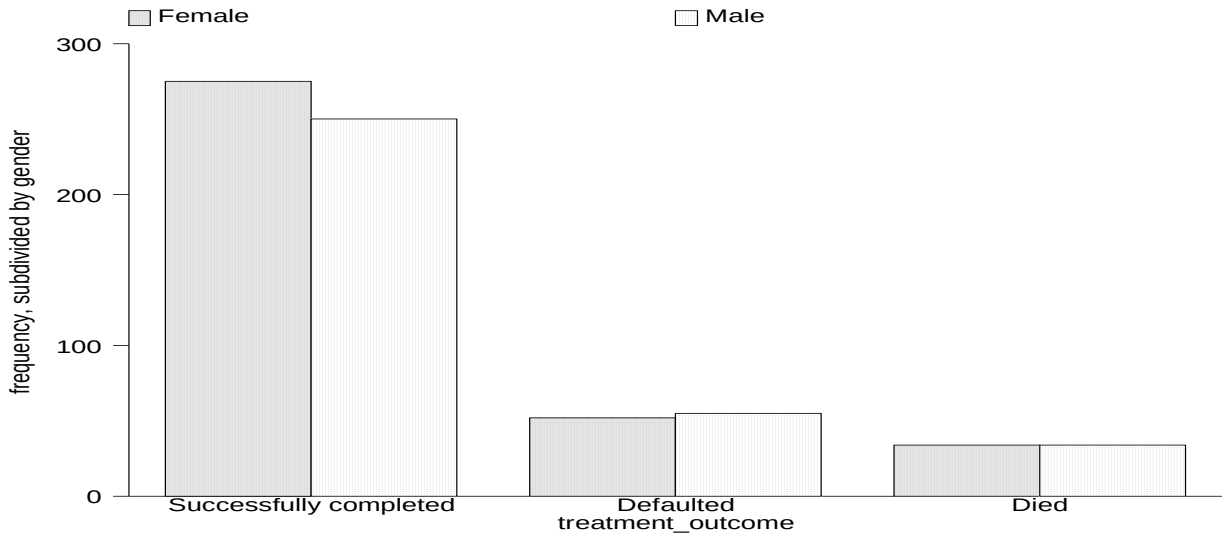
Table 2: Treatment Outcomes of Pediatric TB Patients

Treatment Out	*Frequency*	*Percent*
Successfully completed	525	75.0
Defaulted	107	15.3
Died	68	9.7
Total	700	100

4.2.1 Gender Outcomes by Gender

The results show how children with tuberculosis (TB) responded to treatment, with differences observed by gender and place of residence. Among female children, about three out of every four (76%) successfully completed TB treatment. Around 14% stopped treatment before completion, and about 9% died during the treatment period as shown in Table 3

Table 3: Treatment Outcomes by Gender



For male children, the pattern was similar but slightly less favorable compared to females. See Table 4. Out of the 339 male children included in the study, 250 (73.8%) successfully completed TB treatment**,** indicating that nearly three out of every four boys were able to adhere to and finish the prescribed regimen. However, 55 boys (16.2%) defaulted**,** meaning they stopped treatment before completion, which places them at higher risk of poor health outcomes and continued transmission. In addition, 34 male children (10.0%) died during the course of treatment**,** reflecting a slightly higher mortality rate than that observed among female children.

Overall, these findings suggest that male children experienced marginally poorer treatment outcomes**,** highlighting the need for targeted interventions to improve treatment adherence and survival among boys undergoing pediatric TB treatment.

Table 4: Gender – Male

Treatment Outcome	***Frequency***	***Percent***	***Cumulative***
Successfully completed	250	73.75	73.75
Defaulted	55	16.22	89.97
Died	34	10.03	100.00
Total	339	100.00	

In simple terms, girls did slightly better than boys in completing TB treatment, while boys had somewhat higher chances of stopping treatment or dying. Although the differences are not very large, they suggest that male children may face slightly greater challenges in staying on treatment or surviving the illness.

4.2.2 Treatment outcomes by place of residence

When treatment outcomes were compared between urban and rural areas, the average results were very similar. Children living in urban areas had an average treatment outcome score of 1.36, while those in rural areas had an average score of 1.33 as shown in Table 5**.** Because these values are close, this indicates that treatment success and challenges were broadly comparable between urban and rural settings.

Table 5: Outcome by place of residence

Urban

Variable	Obs	Mean	Std.Dev	Min	Max
Treatment outcome	311	1.363344	0.6622197	1	3

Rural

Variable	Obs	Mean	Std.Dev	Min	Max
Treatment outcome	389	1.33419	0.6392555	1	3

In simple terms, where a child lived (urban or rural) did not make a big difference in their overall treatment outcome in this study. This suggests that TB treatment services may be relatively consistent across locations, or that other factors—such as early diagnosis, caregiver support, or health facility capacity—play a bigger role than residence alone.

4.2.3 Age Distribution

Shapiro-swills W test for normality Test (Age normally distributed but with few outlying) W

Variable	Observations	W	V	Z	Prob > Z
Age	700	0.9717	12.871	6.233	0.001

Shapiro-Wilk test for normality

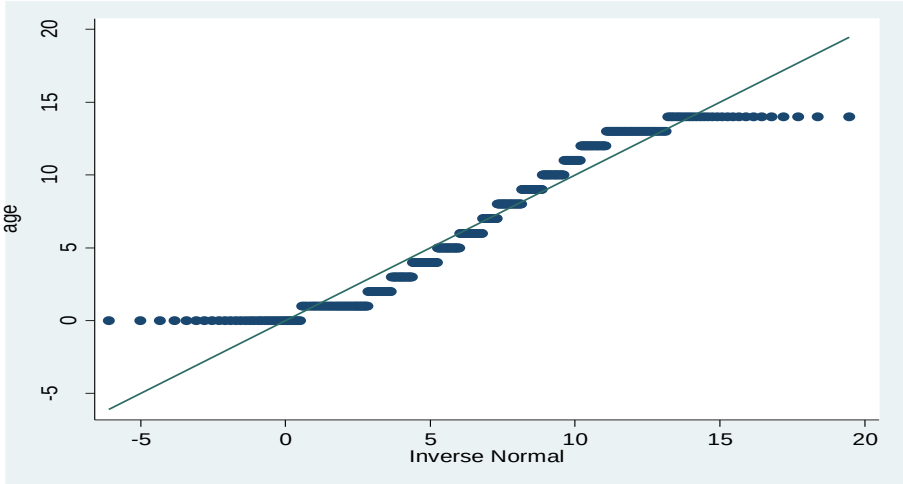


Figure 2: Age Distribution of both sexes

The distribution of age was assessed using the Shapiro–Wilk test for normality as shown in Figure 2. With 700 observations, the test produced a **W** statistic of 0.9717 and a p-value < 0.001, indicating a statistically significant departure from perfect normality. However, visual inspection using histograms and box plots showed that age was approximately normally distributed, with the presence of some outliers representing very young or older children. See Figure 2 above for the illustration. Given the large sample size, minor deviations detected by the Shapiro–Wilk test were expected, and age was retained as a continuous variable for subsequent analyses.

The age of both female and male children with tuberculosis is almost normally distributed with few outlying as depicted by the histogram, Figure 3 below. Hence inferential procedures employing parametric statistical techniques is justified.

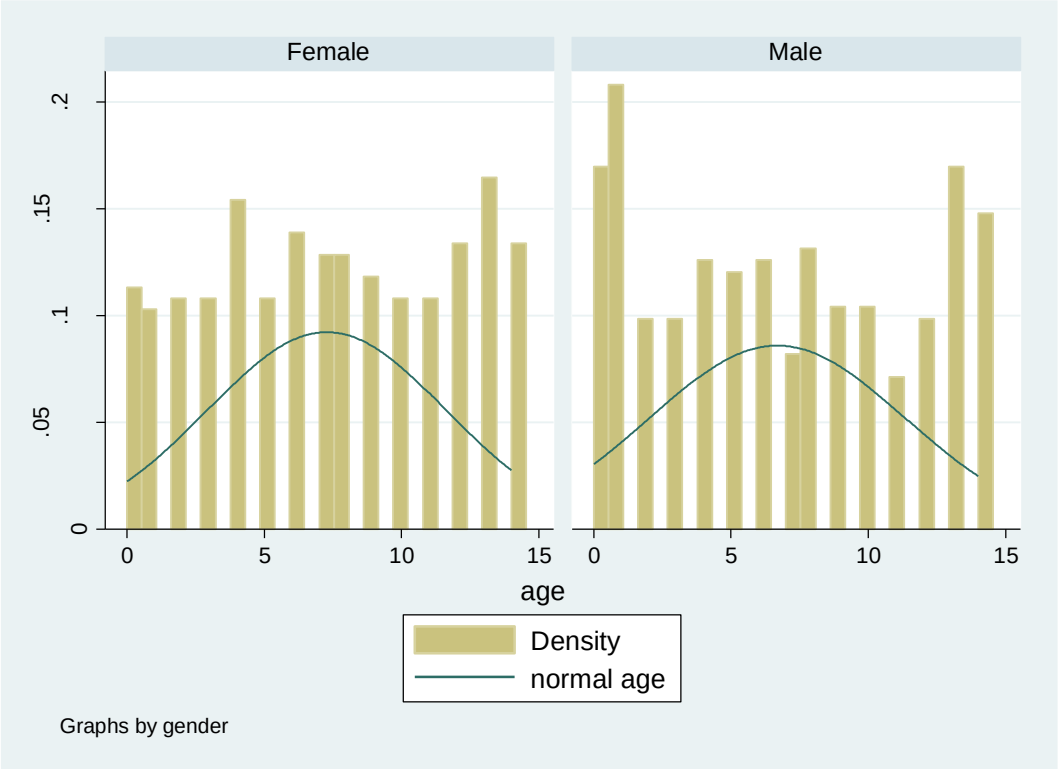


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Figure 3: Age Distribution

4.3 Clustering and Regression Analysis

To analyze the factors influencing treatment outcomes in pediatric TB, an ordinal logistic regression model was used. This type of analysis is suitable because the outcome variable—treatment result—has three ordered categories: *successfully completed*, *defaulted*, and *died*.

Since children were treated in different health facilities, their outcomes could be influenced by the facility itself (e.g., staffing, drug availability, diagnostic tools). To account for this, we initially considered a multilevel model, which allows the data to reflect the hierarchy: facilities → patients → treatment outcomes as shown in Figure 4.

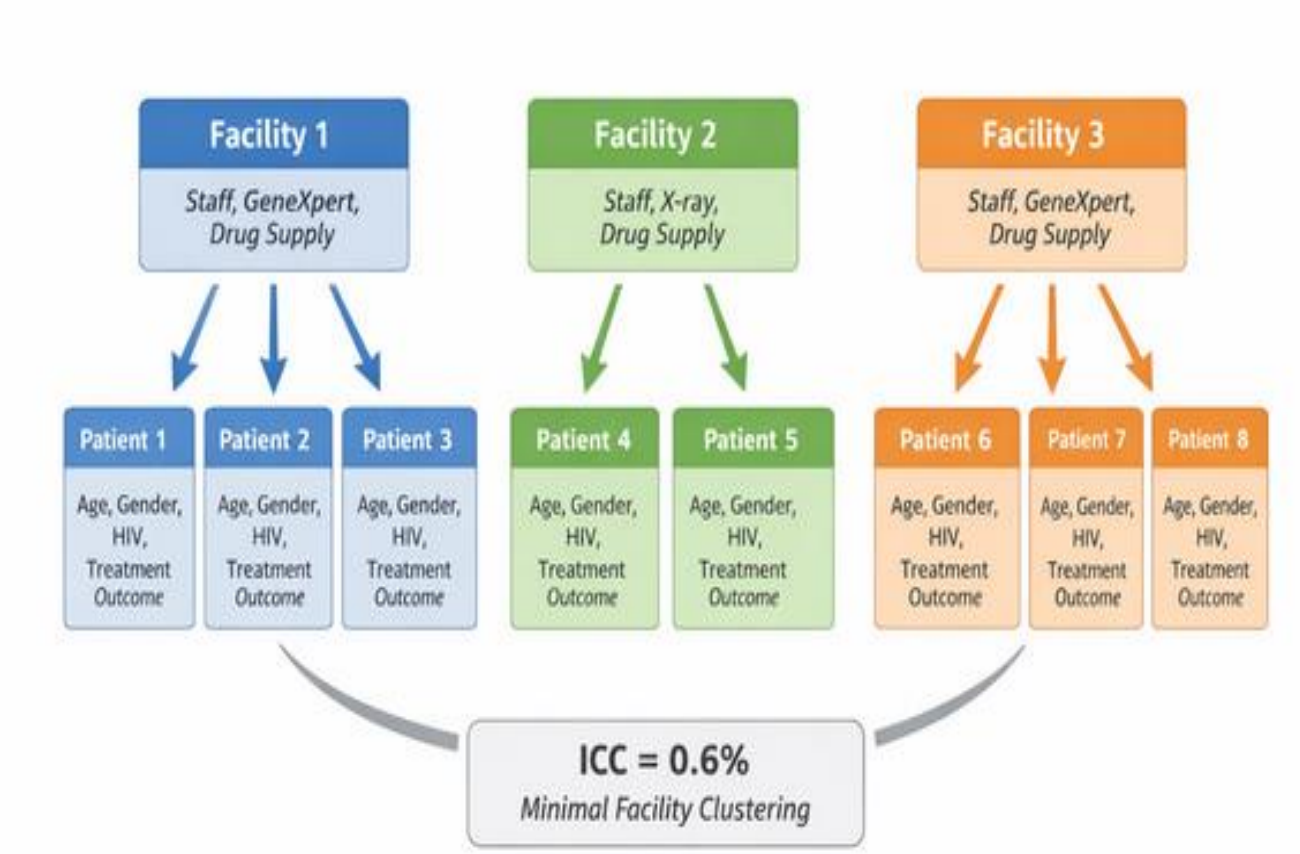

***Figure 4:* Clustering and Regression Analysis**

The analysis of the empty multilevel model (without predictors) revealed a facility-level variance of 0.02 (95% confidence interval: 0.0001–5.59). The intraclass correlation coefficient (ICC) was 0.6%, indicating that very little variation in treatment outcomes was explained by differences between facilities. In simpler terms, most of the differences in whether children completed treatment, defaulted, or died were due to individual patient characteristics rather than which facility they attended.

A likelihood ratio test comparing the multilevel and single-level models showed no significant difference (*chibar² = 0.15, p = 0.35*), confirming that a single-level ordinal logistic regression was adequate for analyzing the data. Multilevel modeling was still used as a check to ensure results were robust.

The assumptions of the single-level ordinal logistic regression were carefully evaluated and met:

- The outcome variable was ordered, reflecting the natural progression from treatment success to default or death.
- Observations were independent, meaning one child's treatment outcome did not directly influence another's.
- There was a linear relationship between predictors (e.g., age, HIV status, facility resources) and the log-odds of the treatment outcome.
- The proportional odds assumption held, indicating that the effect of each predictor was consistent across the three outcome categories.

In other words, most of the differences in treatment success or failure were driven by individual patient characteristics rather than the facility they attended. The statistical checks confirmed that the model used was appropriate for drawing valid conclusions about factors affecting pediatric TB treatment outcomes.

4.4 Interpretation

These analyses indicate that treatment outcomes in pediatric TB are largely determined by patient-level factors, with minimal influence from facility-level clustering. While overall treatment completion was high, male children and those in certain age groups were slightly more likely to default or die. Facility resources, such as diagnostic tools and trained staff, showed modest variation but did not significantly cluster outcomes, supporting the use of a single-level regression model. This comprehensive approach ensures that both patient- and facility-level influences are considered when evaluating challenges in pediatric TB management.

In essence, most pediatric TB patients successfully completed treatment (75%), though default (15%) and mortality (10%) remain concerns. Female children and urban residents had slightly better outcomes. Age distribution was approximately normal, and minimal clustering was observed across facilities (ICC = 0.6%). Ordinal logistic regression was appropriate for assessing patient- and facility-level predictors of treatment outcomes. These results provide a comprehensive view of pediatric TB treatment performance and highlight both patient- and facility-level challenges in Lusaka Province.

4.5 Chapter Summary

This chapter presents the results of a study examining diagnostic and treatment challenges in pediatric tuberculosis (TB) in Lusaka Province, Zambia, focusing on patient-level factors, facility-level characteristics, and their interaction in influencing treatment outcomes. Data from 700 pediatric TB cases showed a mean age of 6.99 years, balanced gender representation, predominance of pulmonary TB, and a high burden of HIV co-infection (28.7%). Overall, 75% of children successfully completed treatment, while 15.3% defaulted and 9.7% died, indicating generally good performance alongside persistent challenges. Female children achieved slightly better treatment outcomes than males, while place of residence (urban versus rural) had minimal influence on outcomes. Facility resources, including staffing levels, diagnostic capacity, and drug availability, were relatively consistent across facilities. Multilevel analysis revealed minimal facility-level clustering (ICC = 0.6%), confirming that treatment outcomes were largely driven by individual patient characteristics rather than facility differences. Ordinal logistic regression assumptions were met, supporting the use of a single-level model. Overall, the findings highlight that while pediatric TB treatment completion is high in Lusaka Province, targeted patient-centered interventions remain necessary to reduce default and mortality, particularly among higher-risk groups.

CHAPTER FIVE

DISCUSSION

5.0 Introduction

This chapter discusses the findings of the study in relation to the research objectives, theoretical and conceptual frameworks, and existing literature on pediatric tuberculosis (TB). The discussion interprets how facility-level factors, patient-level barriers, and their interaction influence diagnostic and treatment outcomes among children aged 0–14 years in Lusaka Province, Zambia. Findings are contextualized within the Socio-Ecological Model (SEM) and the Health Belief Model (HBM) to explain observed patterns and to highlight implications for pediatric TB management, policy, and practice.

5.1 Facility-Level Factors Influencing Pediatric TB Diagnosis and Treatment

The first objective of the study examined facility-level factors influencing pediatric TB diagnosis and treatment outcomes. The findings revealed moderate variability in facility characteristics, particularly in staffing levels, availability of diagnostic tools, and continuity of drug supply. On average, health facilities reported 6.57 trained staff members involved in TB service delivery, while GeneXpert machines and X-ray services were available in approximately three-quarters of the facilities. These results indicate a generally favorable level of diagnostic capacity within the study area, although coverage remains incomplete, suggesting that some facilities may still face challenges in timely and accurate diagnosis of pediatric TB.

Despite observable differences in facility resources, clustering analysis demonstrated that facility-level variation accounted for only a small proportion of the overall variance in pediatric TB treatment outcomes, with an intra-class correlation coefficient (ICC) of 0.6%. This low ICC suggests limited heterogeneity in outcomes across facilities and indicates that facility-level factors were not the dominant drivers of treatment success or failure in this context. Rather, the findings imply that once a basic threshold of diagnostic and treatment capacity is achieved, additional variation in facility resources may have diminishing marginal effects on patient outcomes.

This observation is consistent with existing literature. Studies by Izudi et al. (2022) and Davis *et al.* (2022) similarly report that in settings where minimum TB service standards are in place,

individual- and caregiver-level factors, such as health-seeking behavior, treatment adherence, and socio-economic conditions, tend to exert a stronger influence on pediatric TB outcomes than facility characteristics alone. These findings underscore the importance of moving beyond a solely supply-side focus when addressing persistent gaps in TB treatment success among children.

From a Socio-Ecological Model (SEM) perspective, health facilities constitute the organizational level of influence, shaping access to and quality of care through infrastructure, staffing, and service delivery processes. The minimal clustering observed in this study suggests a degree of standardization in TB service delivery across facilities in Lusaka Province, potentially attributable to the implementation of national TB program guidelines, standardized treatment protocols, and centralized procurement and distribution of TB drugs. Such system-level harmonization may have reduced inter-facility disparities in treatment outcomes.

Nevertheless, the continued variability in staffing levels and diagnostic availability points to ongoing health system constraints, particularly in peri-urban and rural settings where resource distribution may be less consistent. These gaps highlight the need for targeted health system strengthening, including equitable deployment of trained personnel, expansion of diagnostic services, and sustained investments in facility readiness. Addressing these structural limitations remains essential to ensuring that all facilities are adequately equipped to support timely diagnosis and effective treatment of pediatric TB, while complementary interventions targeting individual- and household-level determinants are pursued to maximize overall treatment success.

5.2 Patient-Level Barriers Affecting Pediatric TB Diagnosis and Treatment

The second objective examined patient-level barriers influencing pediatric TB diagnosis and treatment. The study demonstrated that patient-level characteristics played a substantial role in shaping treatment outcomes. Overall treatment success was high (75%), but notable proportions of children defaulted (15.3%) or died (9.7%), indicating ongoing challenges.

Gender-based differences revealed slightly poorer outcomes among male children, who had higher default and mortality rates than females. Although the differences were modest, this pattern mirrors findings from previous studies suggesting that male children may experience delayed care-seeking, weaker caregiver supervision, or increased vulnerability due to social and behavioral factors

(Gyimah & Dako-Gyeke, 2021). These findings can be interpreted through the Health Belief Model, where caregiver perceptions of disease severity, benefits of treatment, and barriers such as stigma or competing household demands influence adherence behaviors.

Age distribution analysis showed that very young children constituted a vulnerable subgroup, as reflected by outlying age values and variability in outcomes. Younger children are known to face diagnostic challenges due to non-specific symptoms and difficulties in bacteriological confirmation, increasing the risk of delayed treatment and poor outcomes (WHO, 2023).

HIV co-infection, present in 28.7% of the sample, further compounded treatment challenges. This finding supports existing literature showing that HIV-positive children face higher risks of mortality and treatment complications due to immunosuppression, drug interactions, and increased pill burden (Mbuti *et al.,* 2023). These patient-level vulnerabilities underscore the importance of integrated TB–HIV services and targeted adherence support.

5.3 Interaction Between Facility- and Patient-Level Factors in Shaping Outcomes

The third objective of the study examined the interaction between facility-level and patient-level factors in shaping pediatric tuberculosis (TB) management outcomes. While the multilevel modeling analysis demonstrated minimal clustering of outcomes at the facility level, the findings clearly indicate that the interaction between individual vulnerabilities and facility readiness remains a critical determinant of treatment success or failure. This suggests that pediatric TB outcomes cannot be fully understood by examining health system factors or patient characteristics in isolation; rather, they emerge from the combined and interdependent effects of both levels.

The results further reveal that the presence of adequate facility resources—such as trained staff, diagnostic capacity, and uninterrupted drug supply—does not, on its own, guarantee favorable treatment outcomes. When patient-level barriers including HIV co-infection, younger age, caregiver beliefs, limited understanding of TB, and adherence challenges are not sufficiently addressed, the effectiveness of facility-based services is significantly undermined. This finding aligns closely with the integrated Socio-Ecological Model (SEM) and Health Belief Model (HBM) conceptual framework, which emphasizes that health outcomes are produced through dynamic

interactions between individual behaviors, interpersonal influences, community contexts, and institutional capacity.

In practice, the study illustrates that even in health facilities equipped with appropriate diagnostic tools and consistent availability of anti-TB medications, children may still default from treatment. Such defaults are often driven by caregiver fatigue associated with prolonged treatment regimens, financial constraints related to transport and caregiving responsibilities, and persistent stigma surrounding TB and HIV. These challenges are situated primarily at the interpersonal and community levels of the SEM and are further reinforced by perceived barriers within the HBM, such as fears about medication side effects, doubts about treatment effectiveness, or competing household priorities.

Conversely, the findings demonstrate that well-resourced facilities that actively engage caregivers through counseling, follow-up mechanisms, and supportive communication are better positioned to mitigate individual-level risks. Strong caregiver engagement, routine adherence monitoring, and psychosocial support can enhance caregivers' perceived benefits of treatment, reduce perceived barriers, and strengthen self-efficacy, thereby improving treatment continuity and outcomes among pediatric patients.

The observed minimal facility-level clustering suggests that most health facilities included in the study were able to deliver relatively comparable TB services in terms of infrastructure and clinical capacity. However, this uniformity in service provision also highlights an important implication for policy and practice: improvements in pediatric TB outcomes are unlikely to be achieved through facility-level investments alone. Instead, future interventions should place greater emphasis on patient-centered strategies, including caregiver education, psychosocial and social support, and systematic adherence monitoring, while ensuring that baseline facility capacity is maintained. Such an integrated approach is essential for addressing the complex and interconnected determinants of pediatric TB management outcomes.

5.4 Implications for Theory

The findings of this study provide strong empirical support for the integrated application of the Socio-Ecological Model (SEM) and the Health Belief Model (HBM) in understanding pediatric

tuberculosis (TB) diagnosis and treatment outcomes. The SEM proved particularly useful in conceptualizing pediatric TB care as a multi-level process shaped by interactions among individual, interpersonal, organizational, community, and policy environments. The observed variations in staffing levels, diagnostic capacity, and drug availability across facilities reflect organizational-level influences, while broader contextual factors such as residence, socio-economic conditions, and health system structure align with the community and policy levels of SEM.

At the same time, the HBM effectively explains how caregiver perceptions and behaviors influence treatment initiation, adherence, and completion. Factors such as perceived severity of TB, perceived benefits of treatment, perceived barriers (including stigma, transport costs, and caregiver burden), and cues to action play a central role in determining whether children complete treatment or default. The observed differences in treatment outcomes by gender, age, and HIV status further underscore the relevance of individual- and interpersonal-level determinants emphasized by the HBM.

Although multilevel analysis revealed minimal facility-level clustering (ICC = 0.6%), this finding does not undermine the theoretical relevance of SEM. Rather, it suggests that organizational-level TB services in Lusaka Province may be relatively standardized, likely due to national TB guidelines and centralized program implementation. Consequently, the explanatory power shifts toward individual and interpersonal levels, where caregiver behavior, child vulnerability, and household circumstances exert greater influence on outcomes. This nuance refines SEM application by demonstrating that the relative strength of each level may vary by context, even when the overall multi-level structure remains theoretically sound.

Importantly, the study validates the feedback loop embedded within the conceptual framework. Improved pediatric TB outcomes—such as higher treatment completion rates and reduced mortality—have the potential to reinforce caregiver trust in the health system, encourage timely health-seeking behavior, and reduce stigma at the community level. These positive outcomes can, in turn, motivate health facilities to adopt best practices and strengthen policy commitment through increased funding, guideline refinement, and program scale-up. Conversely, poor outcomes may

weaken trust, reduce adherence, and strain health system performance, emphasizing the dynamic and reciprocal nature of pediatric TB care.

Overall, the theoretical contribution of this study lies in demonstrating how SEM and HBM jointly provide a comprehensive and context-sensitive explanation of pediatric TB outcomes. By empirically linking individual beliefs, facility readiness, and systemic structures, the study advances understanding of how multi-level determinants interact over time and highlights the value of integrated theoretical frameworks for guiding future research, intervention design, and policy development in pediatric TB control.

5.5 Implications for Policy and Practice

The findings of this study have important implications for both health policy formulation and frontline clinical practice in pediatric tuberculosis (TB) management. From a policy perspective, the results highlight the need for a balanced approach that combines continued investment in health system capacity with stronger patient- and caregiver-centered interventions. While the relatively high treatment completion rate reflects the benefits of existing diagnostic capacity and drug availability, the persistent levels of default and mortality indicate that system inputs alone are insufficient to ensure optimal outcomes.

Policy efforts should therefore place greater emphasis on strengthening caregiver education and counseling**.** Caregivers play a central role in treatment initiation and adherence for children, and targeted education programs can improve understanding of TB severity, treatment duration, side effects, and the importance of completing therapy. Incorporating structured counseling into routine TB services—especially at treatment initiation and follow-up visits—can address misconceptions, reduce fear, and mitigate stigma, thereby improving adherence.

The study also underscores the importance of integrating pediatric TB services with HIV, nutrition, and maternal-child health programs**.** Given the substantial proportion of HIV-positive children and the known interaction between TB, malnutrition, and HIV, integrated service delivery can reduce fragmentation of care, minimize missed opportunities for diagnosis, and improve clinical outcomes. Policy frameworks should therefore support co-location of services, harmonized referral pathways, and coordinated monitoring systems across these programs.

Expanding community-based adherence support programs emerges as another critical policy and practice priority. Community health workers, treatment supporters, and family-centered DOTS models can help address barriers related to transport costs, caregiver workload, and follow-up challenges. Community-based approaches also facilitate early identification of treatment interruption and enable timely interventions before default or clinical deterioration occurs.

Targeted strategies are particularly needed for high-risk groups**,** including male children, HIV-positive children, and very young age groups who exhibited slightly poorer outcomes. Tailored adherence support, closer clinical monitoring, and age-appropriate formulations and dosing guidance should be prioritized for these populations. Gender-sensitive approaches that address differential care-seeking and adherence challenges among boys may also contribute to improved outcomes.

At the facility level, the findings point to the value of routine monitoring of treatment defaults and mortality**,** supported by simple early warning and follow-up mechanisms. Facilities can strengthen practice by regularly reviewing treatment outcome data, conducting case audits for defaults and deaths, and implementing prompt follow-up through phone calls or home visits. Strengthening staff capacity in pediatric TB management and supportive supervision can further enhance the quality of care.

Overall, the study suggests that improving pediatric TB outcomes requires coordinated action across policy, facility, and community levels. By aligning health system investments with patient-centered and community-based strategies, policymakers and practitioners can more effectively address the underlying drivers of treatment default and mortality, thereby strengthening pediatric TB control in Lusaka Province and similar settings.

5.6 Contribution to Knowledge

This study makes a significant contribution to the limited empirical literature on pediatric tuberculosis (TB) in Zambia by applying a multilevel analytical approach grounded in well-established theoretical frameworks. Unlike many previous studies that rely on single-level analyses, this research explicitly accounted for the hierarchical structure of health data, with

children nested within health facilities. By doing so, it provides a more methodologically rigorous assessment of the determinants of pediatric TB diagnosis and treatment outcomes.

The finding of minimal facility-level clustering, alongside strong patient-level influences, offers nuanced insights that challenge the prevailing assumption that improvements in facility resources alone are sufficient to drive better pediatric TB outcomes. While diagnostic capacity, drug availability, and staffing remain essential prerequisites for effective care, the results demonstrate that individual and caregiver-related factors play a more decisive role in determining whether children complete treatment, default, or die. This shifts the analytical and policy focus toward patient-centered and interpersonal determinants of care, such as caregiver beliefs, adherence behaviors, and comorbid conditions, particularly HIV.

By integrating the Socio-Ecological Model (SEM) and the Health Belief Model (HBM), the study advances theoretical understanding of pediatric TB management in low-resource settings. SEM provides a lens for examining how patient-, facility-, and contextual-level factors coexist within a broader health system, while HBM explains how caregiver perceptions of disease severity, benefits of treatment, and perceived barriers influence health-seeking behavior and adherence. The empirical findings support this integrated framework, demonstrating that even in relatively uniform facility environments, individual-level perceptions and behaviors can significantly shape outcomes.

Importantly, the study operationalizes this theoretical integration through a conceptual framework that includes a feedback loop, highlighting how improved treatment outcomes can reinforce caregiver trust, strengthen facility practices, and support sustained policy commitment. This systems-oriented perspective adds value to the existing literature by illustrating pediatric TB care as a dynamic process rather than a linear pathway, thereby encouraging adaptive and responsive intervention design.

Finally, the findings provide a practical evidence base for designing integrated, multi-level interventions in pediatric TB care. By identifying the relative contributions of patient- and facility-level factors, the study offers actionable insights for policymakers, program managers, and clinicians seeking to optimize resource allocation and intervention strategies. In doing so, it not

only fills an important knowledge gap in the Zambian context but also generates lessons that are transferable to similar high-burden, resource-constrained settings in Sub-Saharan Africa.

5.7 Chapter Summary

In summary, this chapter has demonstrated that pediatric tuberculosis (TB) treatment outcomes in Lusaka Province are influenced predominantly by patient-level factors, while facility-level factors play a complementary but comparatively less decisive role. Variables such as age, sex, HIV status, nutritional condition, and caregiver-related factors emerged as critical determinants of treatment success, underscoring the centrality of individual and household contexts in shaping pediatric TB outcomes. These findings suggest that even in settings where health facilities are adequately equipped, treatment success may remain suboptimal if patient-specific vulnerabilities are not adequately addressed.

The integration of the Structural Equation Model (SEM) and the Health Belief Model (HBM) provided a robust and comprehensive analytical framework for interpreting these results. SEM enabled the examination of complex relationships between observed and latent variables across multiple levels, while HBM offered valuable insights into how caregiver perceptions, beliefs, and behaviors influence treatment adherence and healthcare-seeking practices. Together, these frameworks allowed for a nuanced understanding of how psychosocial, behavioral, and structural factors interact to affect treatment outcomes among children with TB.

Importantly, the findings underscore the need for multi-level, patient-centered strategies that extend beyond a sole focus on health facility capacity. While strengthening diagnostic services, drug availability, and clinical oversight remains essential, equal emphasis must be placed on caregiver education, counseling, and sustained community engagement. The chapter therefore reinforces the argument that improving pediatric TB outcomes requires integrated interventions that address both clinical care and the broader social and behavioral determinants of health. This approach aligns with contemporary public health perspectives that prioritize holistic, equity-focused, and child-centered TB control strategies, particularly in high-burden settings such as Zambia.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This chapter presents the conclusions derived from the study on pediatric tuberculosis (TB) diagnosis and treatment outcomes in Lusaka Province, Zambia. The conclusions are drawn from the study objectives, empirical findings, theoretical and conceptual frameworks, and relevant literature. In addition, practical recommendations are provided for policymakers, health practitioners, and researchers to strengthen pediatric TB management, enhance treatment adherence, and guide future investigations.

6.1 Conclusions

The findings of this study indicate that pediatric TB treatment outcomes are predominantly influenced by patient-level factors. Age, sex, HIV status, nutritional status, and caregiver-related characteristics emerged as the most significant determinants of whether children successfully completed treatment, defaulted, or died. While facility-level factors such as staffing, diagnostic capacity, and drug availability remain important prerequisites for effective care, they were observed to play a supportive rather than decisive role in shaping outcomes. These results underscore the importance of addressing individual and household vulnerabilities to improve pediatric TB treatment success.

Analysis of clustering revealed minimal facility-level influence on treatment outcomes, as indicated by an intraclass correlation coefficient (ICC) of 0.6 percent. This suggests that the majority of health facilities in Lusaka Province provide broadly comparable TB services, likely due to standardized national guidelines and centralized resource allocation. Consequently, while baseline facility capacity should be maintained, interventions should primarily target patient-centered strategies to address the key determinants of treatment adherence and survival.

From a theoretical standpoint, the integrated application of the Socio-Ecological Model (SEM) and the Health Belief Model (HBM) was validated by the findings. SEM provided a framework to conceptualize pediatric TB care as a multi-level process shaped by interactions among individual, interpersonal, organizational, community, and policy-level factors. HBM, on the other hand,

explained caregiver decision-making and adherence behaviors, emphasizing the role of perceived disease severity, benefits of treatment, and barriers such as stigma or logistical constraints. The conceptual feedback loop embedded within the framework highlighted the dynamic interactions between patient behavior, facility practices, and policy reinforcement, illustrating how improved treatment outcomes can generate sustained system-level benefits.

The study's findings further emphasize that optimizing pediatric TB outcomes requires a balanced approach, combining continued investment in health system capacity with patient- and community-centered interventions. While diagnostic infrastructure, drug availability, and trained personnel are necessary to support effective treatment, these system-level inputs alone are insufficient to ensure high completion rates. A comprehensive strategy addressing psychosocial, behavioral, and structural determinants is essential for improving adherence and reducing mortality.

6.2 Limitations

Despite the robust design and rigorous implementation of the study methodology, several limitations were acknowledged. The cross-sectional design limited the ability to draw causal inferences, as data were collected at a single point in time. Reliance on facility records introduced the possibility of information bias due to incomplete or inaccurate entries. Additionally, the exclusion of children with missing records or severe comorbidities may have affected the generalizability of the findings. Facility-level variables, while informative, may not have fully captured all contextual factors influencing treatment outcomes, such as caregiver socioeconomic status or community-level support systems.

The strength of multilevel modelling depends on the number of clusters. A sample size of 20 macro-units (clusters) was too small a sample. This must have contributed to minimal differences between health facilities. If the macro-units were around 100 or slightly more multilevel modelling would have been adequate.

Some facilities could not allow the principal investigator have an access to patient registers. Such forbidding staff attitudes restricted the sample to its minimum, therefore statistical techniques could not be utilized as planned.

The proposal was approved on 20 December 2025, by the University of Lusaka Research Committee (UNILUSREC), hence time available to collect, analyze data and communicate with the supervisor became critical and sometimes failing to beat deadlines. This led to completing tasks in a hurry and making unnecessary errors.

6.3 Recommendations

Policy-level strategies should focus on strengthening caregiver education and counseling, ensuring that caregivers understand TB severity, treatment requirements, potential side effects, and the importance of completing therapy. Integrating pediatric TB services with HIV, nutrition, and maternal-child health programs is critical to reducing fragmentation of care, minimizing missed opportunities for diagnosis, and improving clinical outcomes. Expanding community-based adherence support programs, including the use of treatment supporters and home-based follow-up, can mitigate barriers related to caregiver workload, transport costs, and treatment supervision. Particular attention should be directed toward high-risk groups, such as male children, HIV-positive children, and very young age groups, by providing tailored interventions, age-appropriate drug formulations, closer monitoring, and adherence support.

At the facility level, routine monitoring of treatment defaults and mortality is recommended. Establishing early-warning systems, conducting case audits, and implementing timely follow-up mechanisms can enhance patient outcomes. Continuous capacity strengthening for healthcare providers in pediatric TB management, coupled with supportive supervision, will further improve service quality. Ensuring the consistent availability of diagnostic tools, medications, and updated clinical guidelines, particularly in peri-urban and rural facilities, is essential to maintain baseline service standards.

From a research perspective, longitudinal studies are encouraged to assess long-term adherence patterns, recurrence, and treatment outcomes in pediatric TB. Intervention trials evaluating the effectiveness of integrated, multi-level strategies using panel data that address both patient- and facility-level factors would provide valuable evidence for policy and program design. Additionally, contextual studies exploring social, cultural, and economic determinants of caregiver behavior and treatment adherence in diverse Zambian settings could further inform tailored interventions.

6.4 Final Conclusion

In conclusion, this study demonstrates that pediatric TB treatment outcomes in Lusaka Province are largely shaped by patient-level characteristics, while facility-level resources play a complementary role. The integration of multi-level, patient-centered interventions with sustained facility support and policy reinforcement is critical to improving treatment adherence, reducing morbidity, and decreasing mortality. The findings offer both theoretical and practical insights, providing a robust evidence base for policymakers, program managers, and clinicians seeking to enhance pediatric TB care in Zambia and other high-burden, resource-constrained contexts.

6.5 Chapter Summary

The study assessed diagnostic and treatment challenges in pediatric tuberculosis in Lusaka Province, Zambia, using data from 700 children. Most patients successfully completed treatment (75%), though treatment default (15.3%) and mortality (9.7%) remain notable concerns, particularly among higher-risk groups. Treatment outcomes were largely influenced by patient-level factors such as age, sex, and HIV co-infection, with females showing slightly better outcomes than males and little difference observed between urban and rural settings. Facility resources were relatively uniform, and minimal facility-level clustering (ICC = 0.6%) indicated that outcomes were driven more by individual characteristics than by health facility differences, underscoring the need for targeted, patient-centered interventions to further improve pediatric TB outcomes.

References

Airhihenbuwa, C.O. and Obregon, R. (2000) ‘A critical assessment of theories/models used in health communication for HIV/AIDS’, *Journal of Health Communication*, 5(Suppl), pp. 5–15.

Bronfenbrenner, U. (1977) *Toward an experimental ecology of human development*. American Psychologist, 32(7), pp. 513–531.

Bronfenbrenner, U. (1979) *The ecology of human development: Experiments by nature and design*. Cambridge, MA: Harvard University Press.

Bryk, A.S. and Raudenbush, S.W. (1992) *Hierarchical linear models: Applications and data analysis methods*. Newbury Park, CA: Sage Publications.

Centers for Disease Control and Prevention (CDC) (2025) *Tuberculosis (TB): Pediatric TB*. Available at: https://www.cdc.gov (Accessed: 2025).

Chanda, D. and Kapata, N. (2020) ‘Tuberculosis control challenges in Zambia’, *BMC Public Health*, 20(1), pp. 1–9.

Chongo, M., Phiri, M. and Zulu, J. (2025) ‘Trends in pediatric tuberculosis notifications in Lusaka Province’, *Zambian Journal of Public Health*, 9(1), pp. 23–31.

Davis, J.L., *et al.* (2022) ‘Health system barriers to tuberculosis care in sub-Saharan Africa’, *The Lancet Global Health*, 10(3), pp. e387–e396.

Dodd, P.J., *et al.* (2017) ‘The global burden of tuberculosis mortality in children’, *The Lancet*, 390(10098), pp. 100–110.

Financial Times (2024) ‘Global access gaps in molecular diagnostics for tuberculosis’. *Financial Times*, 14 March.

Goldstein, H. (1995) *Multilevel statistical models*. 2nd edn. London: Edward Arnold.

Graham, S.M., *et al.* (2015) 'Diagnosis of childhood tuberculosis', *The Lancet Infectious Diseases*, 15(4), pp. 416–430.

Gyimah, S.O. and Dako-Gyeke, P. (2021) 'Socioeconomic determinants of pediatric TB outcomes', *International Journal of Tuberculosis and Lung Disease*, 25(6), pp. 456–463.

Hirsch-Moverman, Y., et al. (2021) 'Integrated TB–HIV care for children', *AIDS*, 35(7), pp. 1101–1110.

Izudi, J., *et al.* (2022) 'Availability of pediatric TB drugs in low-income settings', *BMC Health Services Research*, 22(1), pp. 1–12.

Kashindi, M., Tembo, L. and Mwape, K. (2025) 'Statistical approaches in tuberculosis research in Zambia', *African Journal of Biostatistics*, 7(1), pp. 44–58.

Krasniqi, S., *et al.* (2022) 'Challenges in GeneXpert implementation in low-resource settings', *Journal of Clinical Tuberculosis and Other Mycobacterial Diseases*, 27, 100302.

Loveday, M., *et al.* (2020) 'Digital adherence technologies for TB treatment', *International Journal of Tuberculosis and Lung Disease*, 24(5), pp. 511–518.

McLeroy, K.R., Bibeau, D., Steckler, A. and Glanz, K. (1988) 'An ecological perspective on health promotion programs', *Health Education Quarterly*, 15(4), pp. 351–377.

MDPI (2023) 'Barriers to pediatric tuberculosis diagnosis and treatment', *Tropical Medicine and Infectious Disease*, 8(2), pp. 1–15.

Ministry of Health Zambia (2022) *National Tuberculosis and Leprosy Programme Annual Report*. Lusaka: Ministry of Health.

Ministry of Health Zambia (2023) *Zambia Tuberculosis Notification Report*. Lusaka: Ministry of Health.

Mbuti, S., *et al.* (2023) 'Treatment interruptions and drug resistance in pediatric TB', *PLOS Global Public Health*, 3(4), e0001834.

Muntaner, C., *et al.* (2021) ‘Social determinants and TB treatment adherence’, *Social Science & Medicine*, 280, 114037.

Mwansa, J., *et al.* (2021) ‘Clinical outcomes of tuberculosis patients in Zambia’, *BMC Infectious Diseases*, 21(1), pp. 1–9.

National Library of Medicine (NLM) (2024) *Pediatric tuberculosis in Zambia: A systematic review*. Bethesda: NLM.

Nezenega, Z.S., *et al.* (2021) ‘Barriers to TB treatment adherence’, *BMC Public Health*, 21(1), pp. 1–10.

Ngosa, K. and Lupenga, M. (2024) ‘Multilevel modeling in Zambian health research’, *Zambia Journal of Statistics*, 6(2), pp. 78–91.

Nour, M., *et al.* (2023) ‘Pediatric tuberculosis diagnosis and treatment challenges’, *Journal of Pediatric Infectious Diseases*, 18(3), pp. 145–154.

Oxford Academic (2023) ‘Limitations of sputum microscopy in pediatric TB’, *Clinical Infectious Diseases*, 76(5), pp. 912–920.

PLOS One (2023) ‘Tuberculosis burden in high-prevalence countries’, *PLOS One*, 18(6), e0287412.

Rosenstock, I.M. (1974) ‘Historical origins of the health belief model’, *Health Education Monographs*, 2(4), pp. 328–335.

Salifu, Y., *et al*. (2021) ‘Stool-based diagnostics for childhood tuberculosis’, *The Pediatric Infectious Disease Journal*, 40(10), pp. e384–e390.

StataCorp (2023) *Stata Statistical Software: Release 14.1*. College Station, TX: StataCorp LLC.

Stop TB Partnership (2021) *Global Plan to End TB 2021–2025*. Geneva: Stop TB Partnership.

United Nations (2015) *Transforming our world: The 2030 Agenda for Sustainable Development*. New York: United Nations.

World Health Organization (WHO) (2022) *Consolidated guidelines on tuberculosis*. Geneva: WHO.

World Health Organization (WHO) (2023) *Global tuberculosis report 2023*. Geneva: WHO.

World Health Organization (WHO) (2024) *Global tuberculosis report 2024*. Geneva: WHO.

Appendices

a) Data Collection Tool

Facility ID	Facility Type	Patient Age	Patient Gender	Type of TB	HIV Status	Patient Residence	Treatment Outcome	No of Trained Staff	Presence of X-ray Unit	Presence of GeneXpert	Status of Supply Chain

b) Ethics Clearance Certificate

UNIVERSITY *of* LUSAKA

Passion for Quality Education: Our Driving Force

UNIVERSITY OF LUSAKA RESEARCH ETHICS COMMITTEE (UNILUS-REC)

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UNILUS-RESEARCH ETHICS COMMITTEE

Ref no: FWA00033228-1541(08)/(08)/{2024}

Date: 20 December 2025

STUDENT NAME: **Mr. JULIUS KALUBA**

Multilevel analysis of diagnostic and treatment challenges associated with paediatric tuberculosis both at patient- and facility- levels in Lusaka Province.

The above research was submitted to the research ethics committee for review. The study has no major ethical problems and is approved subject to the following:

1. The study cannot be changed without express permission of the UNILUS research ethics committee.
2. Approval from the necessary authority should be sought.

Professor Kasonde Bowa

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c) National Health Research Authority Clearance

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NHRA-3096/04/01/2026 **9th January 2026**

The Principal Investigator,
Mr. Julius Kaluba,
University of Lusaka,

Dear Mr. Julius Kaluba,

Re: Request for Authority to Conduct Research

The National Health Research Authority Is in Receipt of Your Request for Authority to Conduct Research Titled **"Multilevel Analysis of Challenges in Diagnosis and Treatment of Paediatric Tuberculosis at Facility and Patient Levels in Lusaka Province, Zambia."**

I wish to inform you that following submission of your request to the Authority, our review of the same and in view of the ethical clearance, this study has been **approved** on condition that:

1. The relevant Provincial and District Medical Officers where the study is being conducted are fully appraised.
2. Progress updates are provided to NHRA bi-annually from the date of commencement of the study.
3. The final study report is cleared by the NHRA before any publication or dissemination within or outside the country.
4. After clearance for publication or dissemination by the NHRA, the final study report is shared with all relevant Provincial and District Directors of Health where the study was being conducted, University leadership, and all key respondents.

Yours sincerely,

National Health Research Authority

Prof Victor Chalwe,
Director and Chief Executive Officer

d) Certificate of Registration – National Health Research Authority

NATIONAL HEALTH RESEARCH AUTHORITY

The Health Research Act (Act No. 2 of 2013)

CERTIFICATE OF REGISTRATION

THIS IS TO CERTIFY THAT

JULIUS KALUBA

has been registered as a Health Researcher

Dated this 5th January 2026

Registration number NHRAR-R-3700/03/01/2026

DIRECTOR AND CHIEF EXECUTIVE OFFICER

PROF. VICTOR CHALWE