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The Impact of Vaccination Programs on the Prevention of Infectious Disease Tuberculosis: A Case Study with Gasabo District in Rwanda

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ABSTRACT

➢ ***Introduction***

Tuberculosis (TB) remained a significant public health challenge globally, including in Gasabo District, Rwanda. Vaccination programs, particularly Bacille Calmette-Guérin (BCG) vaccination, played a crucial role in TB prevention. This study aimed to assess the impact of vaccination programs on TB prevention in Gasabo District, Rwanda, by analyzing vaccination coverage, TB incidence rates, demographic characteristics, and healthcare system factors.

➢ ***Methods***

A retrospective cohort study design was employed, utilizing secondary data sources from healthcare facilities in Gasabo District. Data on vaccination coverage, TB incidence rates, demographic characteristics, and healthcare system factors were collected and analyzed. Statistical methods, including regression analysis and descriptive statistics, were used to assess the association between vaccination programs and TB prevention outcomes.

➢ ***Findings***

The study found a significant association between BCG vaccination coverage and lower TB incidence rates in Gasabo District. Higher vaccination coverage was associated with reduced TB incidence rates, particularly among children. However, challenges such as incomplete vaccination data, potential confounding factors, and socio-economic disparities were identified. Despite these challenges, vaccination programs were found to be effective in reducing TB transmission and protecting vulnerable populations from TB infection.

➢ ***Conclusion***

The findings highlighted the importance of vaccination programs in TB prevention efforts in Gasabo District, Rwanda. Strengthening vaccination coverage, enhancing healthcare system capacity, addressing socio-economic determinants, fostering collaborations, promoting research and innovation, and strengthening surveillance and monitoring systems are essential for optimizing TB prevention efforts. By implementing these recommendations, we can accelerate progress towards ending the TB epidemic and improving public health outcomes in Gasabo District and beyond.

Keywords:- *Tuberculosis, Vaccination programs, Bacille Calmette-Guérin (BCG), Prevention, Gasabo District, Rwanda.*

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TABLE OF CONTENTS

THE DISSERTATION 873
ABSTRACT 874
TABLE OF CONTENTS 875
ACKNOWLEDGEMENTS 877
DISSERTATION THESIS 878

CHAPTER ONE: INTRODUCTION 879
A. The Country Profile 879
B. The Background Analysis of Tuberculosis Vaccination 880
C. The Burden of Tuberculosis in Rwanda 880
D. Analysis of trends and Outcomes of Infectious Diseases 881
E. The Scope of The Study 882

CHAPTER TWO: LITERATURE REVIEW I 883
A. History of Tuberculosis Profile in Rwanda 883
B. TB prevalence in Rwanda: The 2012 first nationwide study provided crucial TB control insights. 883
C. The Impact of Vaccination Programs on the Prevention of Infectious Diseases Tuberculosis in Kenya 884
D. The Impact of Vaccination Programs on the Prevention of Infectious Diseases Tuberculosis in Uganda 884
E. The Impact of Vaccination Programs on the Prevention of Infectious Diseases Tuberculosis in South Africa 885
F. The Impact of Vaccination Programs on the Prevention of Infectious Diseases Tuberculosis in Ethiopia. 886

CHAPTER THREE: LITERATURE REVIEW II 888
A. The Analysis of the Global Burden and Approach to Tuberculosis Control 888
B. The History of TB and BCG Vaccinations 888
C. Global expenditure on TB vaccinations 889
D. The Tuberculosis Situation in African Regions 889
E. Research Aim 890
- *Research Objective* 890
- *Research Question* 890

F. The Research Gap 890
G. Hypothesis 890
- *Null Hypothesis (H0)* 890
- *Alternative Hypothesis (H1)* 890
- *Additional Hypotheses* 890

CHAPTER FOUR: METHODOLOGY 892
A. The Study Design 892
B. Retrospective Study Design Implications 892
C. The Background Information and Study Site Location 893
- *Background Information* 893
- *Study Site Location* 893

D. Target Population 894
E. The Study Duration 894
F. Sampling and Sample Size Determination 895
G. Data Collection Instrument 895
H. Data Management and Analysis 895
I. Ethical Framework 895
J. The Inclusion and Exclusion Criteria 896
- *Inclusion Criteria* 896
- *Exclusion Criteria* 896

K. The Conceptual Framework 896

CHAPTER FIVE: FINDINGS / ANALYSIS /DISCUSSION 899
A. The Descriptive Statistics 899
B. Suceptibility of TB infection Between Vaccinated Males and Females 899
C. Assessment of vaccination coverage rates among different population groups 900
- *Infants and Children* *900*

D. Adolescents and Adults BCG Vaccination Index 901

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

E. BCG vaccination timeliness, completeness, and the administration of booster doses 901
F. Factors that typically influence vaccination uptake 902
G. Individuals targeted for High risk TB case findings in Gasabo District, Rwanda 903
H. Treatment Regimens 904
I. Infection risks due to the Services Offered 904
J. Characteristics of patients in Rwanda who are co-infected with tuberculosis and HIV 905
K. Prevalence Estimates of Pulmonary Tuberculosis in the Adult Population of Rwanda 906
L. Obtaining sputum culture samples for individuals with a high susceptibility to MDR-TB 906
- *Regression Analaysis* 907
M. ANOVA Analysis 908

STUDY FINDINGS 910

DISCUSSION 912

COMPARISON WITH OTHER STUDY FINDINGS 913

CONCLUDING REMARKS 915

RECOMMENDATIONS 916

REFERENCES 917

APPENDIX 920
- *Suceptibility of TB infection Between Vaccinated Males and Females* 920
- *Adolescents and Adults BCG Vaccination Index* 920
- *Factors that typically influence vaccination uptake* 921
- *Individuals targeted for High risk TB case findings in Gasabo District, Rwanda* 921
- *Prevalence Estimates of Pulmonary Tuberculosis in the Adult Population of Rwanda* 922

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

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RESEARCH STATEMENT

This study investigated the effectiveness of vaccination programs, particularly Bacille Calmette-Guérin (BCG) vaccination, in reducing tuberculosis (TB) incidence rates and preventing TB transmission in Gasabo District, Rwanda. Through a retrospective cohort study design and analysis of secondary data sources, the study aimed to assess the association between vaccination coverage, TB incidence rates, demographic characteristics, and healthcare system factors. By examining the impact of vaccination programs on TB prevention outcomes, this research contributed to the understanding of TB epidemiology and vaccination strategies in resource-constrained settings. The findings provided valuable insights for policymakers, healthcare professionals, and public health stakeholders to optimize TB prevention efforts and improve public health outcomes in Gasabo District and similar regions globally.

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CHAPTER ONE
INTRODUCTION

A. Background Information

Infectious diseases have long been a global public health concern, posing significant threats to populations worldwide. Among these diseases, tuberculosis (TB) stands out as one of the oldest and deadliest infectious diseases known to humanity. Despite advances in medical science and healthcare systems, TB continues to present a formidable challenge, particularly in low- and middle-income countries.

TB normally caused by Mycobacterium tuberculosis, a bacterium that primarily affect the lungs but can also affect other parts of the body. It spreads through the air when an infected person coughs or sneezes, making it highly contagious. TB manifests with symptoms such as persistent cough, fever, weight loss, and night sweats, and if left untreated, it could be fatal.

Vaccination has long been recognized as one of the most effective strategies for preventing infectious diseases, including TB. The Bacille Calmette-Guérin (BCG) vaccine, developed in the early 20th century, remains the only licensed vaccine for TB prevention. BCG vaccination was typically administered during infancy in countries with a high prevalence of TB, aiming to provide protection against severe forms of the disease, particularly in children.

Rwanda, like many other countries in sub-Saharan Africa, faces significant challenges in controlling TB. Despite efforts to improve healthcare infrastructure and access to treatment, TB remained a major public health issue in Rwanda, with a considerable burden on both the healthcare system and the economy. Gasabo District, located in the central part of Rwanda, experiences its share of TB cases, contributing to the broader national and regional TB burden.

B. Overview of the Problem

Globally, TB remained a major cause of morbidity and mortality, especially in resource-limited settings. According to the World Health Organization (WHO), TB was one of the top 10 causes of death worldwide and the leading cause of death from a single infectious agent, ranking above HIV/AIDS. In 2020, an estimated 10 million people fell ill with TB, and 1.5 million died from the disease, with over 95% of TB deaths occurring in low- and middle-income countries.

In Rwanda, TB posed a significant public health challenge despite ongoing efforts to control the disease. The country had made considerable progress in reducing TB incidence and mortality rates in recent years, but challenges such as limited healthcare infrastructure, socioeconomic disparities, and barriers to accessing healthcare services persist. As a result, TB remained a leading cause of morbidity and mortality in Rwanda, with substantial implications for the health and well-being of its population.

Gasabo District, situated in the densely populated Kigali Province, represented a microcosm of the TB epidemic in Rwanda. The district faced unique challenges related to urbanization, poverty, and inadequate healthcare resources, which contributed to the persistence of TB transmission and incidence. Understanding the impact of vaccination programs on TB prevention in Gasabo District was essential for informing public health policies and interventions aimed at reducing the burden of TB at the local, national, and global levels.

In this study, it explored the impact of vaccination programs, particularly the BCG vaccine, on the prevention of TB in Gasabo District, Rwanda. By examining vaccination coverage, TB incidence rates, and other relevant variables, seeked to assess the effectiveness of vaccination strategies in mitigating the TB burden in the region. Through a comprehensive analysis, aimed to provide insights that could inform evidence-based interventions and policy decisions to enhance TB control efforts in Gasabo District and beyond.

C. The Country Profile

The Republic of Rwanda recorded as one of the poorest countries in the world. It is in the Great Lakes area in central Eastern Africa and has a low life expectancy, a high infant mortality rate, and a high death rate. At the moment, about 150 out of every 100,000 adults in Rwanda die from TB, making it the leading cause of death among adults there. Researchers and doctors thought that the next HIV outbreak will cause this number to rise by a huge amount. The disease has been on slow start to look like tuberculosis did in Europe in the 1800s and early 1900s, becoming a major cause of death in the population. It was added to Rwanda's increased immunization program by the government in 2007. Children aged 6 weeks and up were to get the Bacillus Calmette-Guerin (BCG) vaccine against tuberculosis. Scientists who studied the disease thought that this action will have a big effect on the disease. But there isn't any solid proof, and the trend data for TB in Rwanda isn't very reliable. This study aimed to look at how tuberculosis rates have changed in Gasabo district over the past few years and whether the introduction of the BCG vaccine has had any effect. It also tried to figure out whether the success of the BCG vaccine could be a useful public health tool in the fight against TB in Rwanda after the genocide.

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D. The Background Analysis of Tuberculosis Vaccination

Vaccination initiatives have been instrumental in averting tuberculosis (TB), an exceptionally contagious illness precipitated by the Mycobacterium tuberculosis bacterium (Kanabalan et al., 2021). Vaccination initiatives against tuberculosis have substantially decreased the incidence and prevalence of the disease on a global scale. The transmission of tuberculosis has been substantially mitigated by vaccination, especially in densely populated areas such as sub-Saharan Africa and certain regions of Asia, where immunization campaigns have been implemented on a large scale.

One of the most lethal infectious diseases in the world is tuberculosis. There were 10.6 million cases of tuberculosis in 2021, with 1.6 million fatalities (World Health Organization, 2022). Even though tuberculosis was a major problem in world health, no new vaccine against the disease has been approved since Bacille Calmette-Guérin (BCG) more than a century ago. At present, there were sixteen vaccine candidates undergoing clinical trials; however, insufficient funding had primarily impeded the advancement of these candidates and the expansion of the clinical pipeline . Maximum public health and economic advantages will be achieved, the research findings, through immediate and increasing investment in R&D, speedy introduction of vaccinations, and scaling up of their usage once they are accessible.(Aridja et al., 2023)

Also, vaccination initiatives have played a role in the reduction of mortality rates associated with tuberculosis. Through the administration of TB vaccinations, these programs have effectively averted the transmission of life-threatening complications, including disseminated TB and TB encephalopathy, which primarily affect children. As a result, the worldwide distribution of tuberculosis vaccines has preserved innumerable lives (Li et al., 2023).

Vaccination has also demonstrated its efficacy as a cost-effective method of combating tuberculosis. Vaccination programs mitigate the economic burden linked to tuberculosis by preventing cases of the disease. The expenses associated with tuberculosis treatment were significant, encompassing medication, hospitalization, and productivity loss. Vaccination serves to alleviate these financial burdens through the reduction of expensive medical interventions (Martineau, 2023).

In addition, tuberculosis vaccination initiatives have built upon the foundations of healthcare delivery systems and immunization systems, thereby enhancing the public health infrastructure as a whole. Frequently, these programs foster partnerships and capacity-building initiatives that transcend tuberculosis control through collaborations between governments, international organizations, and local healthcare providers(Graham et al., 2015).

Nevertheless, notwithstanding the considerable advantages of vaccination, obstacles persist in the pursuit of attaining comprehensive coverage and efficacy. The most extensively used tuberculosis vaccine, Bacille Calmette-Guérin (BCG), has inconsistent efficacy and does not provide complete protection against the disease, especially in adults. Ongoing research endeavors aimed to develop refined tuberculosis vaccines that exhibited enhanced efficacy and were appropriate for individuals of all age categories.

In 2022, the South-East Asian Region was responsible for the highest number of new tuberculosis (TB) cases, accounting for 46% of the total (Liu et al., 2020). This information was provided by the World Health Organization (WHO). A close second came from Africa, which recorded 23% of new cases, and the Western Pacific area reported 18% of new cases. People who are grownups and are in their prime working years were the ones who were most likely to develop tuberculosis (Migliori et al., 2021). On the other hand, anyone of any age could become infected. Certain factors, such as the following, could make a person more susceptible to harm: A compromised immune system could be brought on by a number of factors, including HIV/AIDS, malnutrition, diabetes, or tobacco use. Undernourishment, in the year 2022 alone, there were around 2.2 million new cases of tuberculosis that were linked to underdevelopment (Choudhary & Parwez, 2022). The cost of tuberculosis can be extremely catastrophic. Half of all tuberculosis patients and their families around the world were at risk of experiencing a financial catastrophe as a result of the disease. These individuals spent more than twenty percent of their family income on medical bills, missed wages, and other expenses. To effectively combat tuberculosis (TB), a multi-pronged approach that prioritizes both treatment and preventative initiatives is required. The worldwide burden of tuberculosis will be reduced as a result of this, and individuals will be protected from the severe effects of the disease.

E. The Burden of Tuberculosis in Rwanda

Tuberculosis (TB) has continued to be a substantial public health issue in Rwanda, notwithstanding continuous endeavors to mitigate its transmission. The prevalence of tuberculosis in the nation has been faced with complexity and comprised a range of socio-economic and health-related elements (Telisinghe et al., 2016). A significant obstacle in the efforts to combat tuberculosis in Rwanda was the disease's high prevalence. Tuberculosis (TB) remained a significant health concern for a substantial segment of the population, especially in marginalized and vulnerable communities, despite notable advancements in recent times. Poverty, congestion, malnutrition, and HIV/AIDS were elements that contributed to the continued transmission of tuberculosis in specific geographical areas (Sapp et al., 2023).

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Moreover, tuberculosis had a significant impact on both morbidity and mortality rates in Rwanda. As the primary cause of mortality and morbidity in the nation, tuberculosis placed a substantial strain on healthcare infrastructure and resources. In addition to impacting the health of individuals, the disease engendered a wider socio-economic ramifications such as diminished productivity, escalated healthcare expenditures, and the exacerbation of poverty.

The situation in Rwanda was further complicated by the co-epidemic of tuberculosis and HIV/AIDS. The immunosuppressive effects of HIV/AIDS rendered individuals more vulnerable to tuberculosis infection, thereby elevating the probability of morbidity and mortality associated with TB (Telisinghe et al., 2016). To effectively tackle TB-HIV co-infection, it was imperative to implement integrated strategies that guarantee universal access to comprehensive healthcare services, such as antiretroviral therapy, TB treatment, and HIV testing.

Additionally, the difficulty in diagnosing and treating tuberculosis further exacerbates the disease's impact in Rwanda. Diagnosis delays, restricted availability of healthcare facilities, and insufficient diagnostic infrastructure impede timely identification and expeditious commencement of treatment. Additionally, stigma, fear of disclosure, and problems with treatment adherence impede the effectiveness of tuberculosis control efforts (Migambi et al., 2020).

F. In spite of these obstacles, Rwanda has achieved notable progress in its fight against tuberculosis by implementing comprehensive strategies and interventions. As TB control was a public health priority, the government had implemented numerous initiatives, such as strengthening healthcare infrastructure, expanding TB diagnostic and treatment services, and establishing community-based TB programs.

In addition, advance in tuberculosis control have been facilitated by Rwanda's partnerships with international organizations and donors, as well as its dedication to attaining universal health coverage. Funding for research, innovation, and capacity-building initiatives provides additional assistance to the nation in its endeavors to mitigate the impact of tuberculosis and enhance the well-being of those impacted.

G. Prevalence of tuberculosis in Rwanda: Results of the first nationwide survey in 2012 yielded important lessons for TB control

According to the findings of the inaugural National Tuberculosis prevalence survey in Rwanda, which was carried out in 2012, the estimated prevalence of smear-positive TB was 74.1 (95% CI 48.8–99.3) per 100,000 adult individuals, while bacteriologically confirmed TB was 119 (95% CI 78.8–159.9) per 100,000 adult individuals. The rate of sputum collection was 99.0%, and the participation rate was 95.7% (Migambi et al., 2020).

In contrast to a number of other nations where national tuberculosis prevalence surveys were recently concluded and prevalence rates exceeded expectations during sampling, the TB prevalence rate in Rwanda was lower than previously estimated by the World Health Organization (Migambi et al., 2020). This reduced incidence of tuberculosis will serve as the foundation for all subsequent efforts to control the disease. Males had a higher incidence of tuberculosis than females; this trend was also documented in other nations. According to the survey, the incidence of tuberculosis in males was five times that of females. However, routine surveillance data only displayed a twofold increase, indicating that males in Rwanda continue to be underdiagnosed. The disparity in routine data that was noted previously in the country may have been attributed to the reduced sensitivity of tuberculosis screening and diagnostic instruments in females relative to males (Migambi et al., 2020).

Based on the present survey data, it can be concluded that the observed distinction between males and females is valid and not a result of the TB detection system's inability to diagnose TB in females. The distinction can subsequently be ascribed to extrinsic or intrinsic (biological) factors. Progesterone and androgens potentially exert an immune suppressive effect, whereas estrogens potentially enhance the immune system.

Male-prevalent risk factors including recurrent tuberculosis infections, malnutrition, HIV infection, smoking, harmful alcohol use, and interior air pollution may also account for the observed disparity. Indeed, the results of this survey indicate that males smoke three times more frequently than females and consume alcohol twice as frequently as females. As both HIV infection and low body mass index are more prevalent among females than males in Rwanda, they do not appear to be explanatory factors (Telisinghe et al., 2016).

H. Analysis of trends and Outcomes of Infectious Diseases

Infectious diseases have historically posed significant threats to public health, causing widespread morbidity and mortality. The development and implementation of vaccination programs have played a pivotal role in mitigating the impact of infectious diseases, offering an effective strategy for preventing their spread and reducing associated health burdens. This research explored the impact of vaccination programs, with a particular focus on tuberculosis (TB) and other infectious diseases, within the context of Gasabo District in Rwanda (Jayawardana et al., 2022).

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Rwanda, like many other developing nations, has grappled with the challenges posed by infectious diseases, leading to adverse effects on public health, economic stability, and overall societal well-being. Gasabo District, located in the central part of Rwanda, serves as a microcosm of the broader health landscape in the country, presenting a unique opportunity for an in-depth examination of the effectiveness of vaccination programs (Jeong & Min, 2023).

Key components of the study included an exploration of the historical context of infectious diseases in Gasabo District, an analysis of the evolution and implementation of vaccination programs, an assessment of vaccination coverage rates, and an examination of the correlation between vaccination initiatives and disease prevalence over time. Furthermore, the study investigated the socio-economic factors influencing vaccine uptake, community perceptions towards vaccinations, and potential challenges faced by health authorities in Gasabo District.

I. The Scope of The Study

The scope of a study on the burden of tuberculosis in Rwanda encompassed various dimensions related to the epidemiology, socio-economic impact, healthcare infrastructure, and interventions aimed at TB control in the country. The following were keenly observed during the study:

- Epidemiological Data: Gathering and analyzing data on the prevalence, incidence, and trends of tuberculosis in Rwanda over time. This involved examining demographic factors, geographical distribution, and disparities in TB burden among different population groups.
- Socio-Economic Factors: Investigating the socio-economic determinants that contributed to the burden of TB in Rwanda, such as poverty, unemployment, education level, housing conditions, and access to healthcare services. Understanding these factors is crucial for identifying vulnerable populations and designing targeted interventions.
- Healthcare Infrastructure: Assessing the capacity and effectiveness of Rwanda's healthcare system in diagnosing, treating, and preventing tuberculosis. This involved evaluating the availability of TB diagnostic tools, laboratory facilities, healthcare personnel, and treatment regimens across different regions of the country.
- TB-HIV Co-infection: Examining the intersection of tuberculosis and HIV/AIDS in Rwanda and its implications for TB control efforts. This activity included assessing the prevalence of TB-HIV co-infection, access to HIV testing and treatment services, and integration of TB-HIV services within the healthcare system.
- Interventions and Policies: Reviewing the existing policies, strategies, and interventions implemented by the Rwandan government and other stakeholders to combat tuberculosis. This would include assessing the effectiveness of TB prevention, diagnosis, treatment, and surveillance programs, as well as community-based initiatives and advocacy efforts.
- Challenges and Opportunities: Identifying the key challenges, barriers, and gaps in TB control efforts in Rwanda, such as limited resources, infrastructure constraints, stigma, and treatment adherence issues. Exploring potential opportunities for strengthening TB control, including innovations in diagnostics, treatment, and healthcare delivery models.
- Recommendations: Providing evidence-based recommendations for improving TB control in Rwanda, based on the findings of the study. This may include suggestions for policy reforms, resource allocation, capacity-building initiatives, community engagement strategies, and collaboration with international partners.

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CHAPTER TWO
LITERATURE REVIEW I

A. *The Background of Tuberculosis in Rwanda and Other Regional States Contributions in Dealing with Tuberculosis History of Tuberculosis Profile in Rwanda*

Since 2002, the Centers for Disease Control and Prevention (CDC) had collaborated with the Rwandan Ministry of Health to enhance its initiatives in various domains. These include HIV testing and counseling, expansion of antiretroviral treatment, interventions for HIV prevention, integration of tuberculosis (TB) and HIV services, strengthening laboratory systems, health informatics, disease surveillance, and monitoring and evaluation (Mbabazi, 2011).

The Centers for Disease Control and Prevention (CDC) prioritized the improvement of clinical services in order to offer complete and integrated HIV prevention and treatment, as well as TB/HIV integrated services, at all Ministry of Health testing and treatment facilities. The CDC contributed to the development of Rwanda's laboratory manpower and infrastructure by enhancing its laboratory systems (Schaivone, 2013). The partnership had facilitated the reduction of turnaround times for the delivery of HIV test results and the enhancement of laboratory informatics utilization by clinicians, hence improving the interaction between the laboratory and clinical settings. In collaboration with the Ministry, the Centers for Disease Control and Prevention (CDC) employed electronic health information systems to facilitate the prevention, detection, treatment, and reporting of HIV.

B. *TB Prevalence in Rwanda: The 2012 First Nationwide Study Provided Crucial TB Control Insights.*

The World Health Organization (WHO) estimated the prevalence and incidence rates of tuberculosis (TB) worldwide in 2012 to be 166 and 122 per 100,000 individuals, respectively. For the African region, the anticipated rates were 303 and 255, respectively (Migambi et al., 2020). The estimated prevalence and incidence rates of tuberculosis in Rwanda are 114 and 86 per 100,000 individuals, respectively. Rwanda reported 6,208 tuberculosis cases in that year, which accounted for 63.3% of the estimated 9,800 incident TB cases. The discrepancy that was noted prompts inquiry into whether the disease prevalence is lower than what the WHO estimates, or if the observed discrepancy arises from inadequate detection or underreporting of tuberculosis cases (Migambi et al., 2020).

According to WHO's projections, Rwanda had a tuberculosis prevalence of 252/100,000 when the study was being planned. According to national experts, the World Health Organization's burden estimates may have been "overestimated" and the actual national burden is lower. A sample size of 70% of the burden estimate was thus determined. A total of 42,598 adults were surveyed based on the following parameters: a 95% participation rate, a relative precision of 23%, a confidence level of 95%, and an anticipated design effect of 1.7 for the adult population of Rwanda, with a prevalence of 176/100,000 for sputum smear positive (SS+) pulmonary (Migambi et al., 2020).

A random sampling technique was used to choose administrative sectors based on their population sizes. Within certain sectors, a basic random sample of communities (Umudugudu) was executed. We aimed to collect data from 610 people per cluster, as 70 clusters were considered feasible from an operational practicality standpoint (Ntivuguruzwa et al., 2022). In addition to housing about 25% of Rwanda’s pulmonary tuberculosis cases, Kigali has a far larger caseload compared to the other provinces. The decision was made to select three additional clusters in Kigali in order to acquire a more precise approximation. To ensure that the Kigali clusters' contributions were evenly distributed, weighting was employed throughout the analysis. The original goal sample size was 44,5 hundred adults, but after adding three more clusters in Kigali, the total number of clusters was 73 (Ntivuguruzwa et al., 2022).

- *Findings*

As in other countries, men had a higher prevalence of tuberculosis than women. It appeared that men in Rwanda were still underdiagnosed with tuberculosis, as the study found a rate five times higher in men than in females, despite the fact that this rate was only twice as high in regular surveillance data. One possible explanation for the discrepancy in routine statistics was that tuberculosis screening and diagnostic techniques were less sensitive for girls than for males, according to previous literature from the country (Bates et al., 2015). This gender gap was real, and the current survey results showed that it was not due to a flaw in the tuberculosis detection method that it couldn’t identify the disease in females. One or more causes, either internal (biological difference) or external (environmental influence), might be responsible for the discrepancy. The immune system might have been strengthened by estrogens, but weakened by progesterone and androgens. Possible explanations for the disparity included male-prevalent risk factors such as tuberculosis (TB) infections, malnutrition, HIV infection, smoking, hazardous alcohol use, and indoor air pollution (Bisht et al., 2023). Specifically, men reported drinking twice as often as women and smoking three times more frequently than women, according to this survey. The fact that HIV was more common in women than men in Rwanda suggested that being underweight or having an unhealthy lifestyle couldn’t be the cause.

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C. The Impact of Vaccination Programs on the Prevention of Infectious Diseases Tuberculosis in Kenya

Vaccination initiatives have been instrumental in curbing the prevalence of tuberculosis (TB) in Kenya, thereby substantially diminishing the disease's burden. TB-protecting Bacille Calmette-Guérin (BCG) vaccine was routinely administered to neonates in Kenya as a component of the national immunization program (Warr et al., 2022). Based on data provided by the Kenyan Ministry of Health, annual vaccination coverage for infants against the BCG had remained consistently high, exceeding 90%. Increasing vaccination rates had played a role in the reduction of tuberculosis incidence rates among minors, a demographic that is especially susceptible to the most severe manifestations of the illness.

In addition, vaccination programs have reduced the prevalence of tuberculosis among the general populace in Kenya, thereby exerting a more extensive influence on TB transmission and control. Research findings indicated that the administration of BCG vaccination not only safeguards vaccinated individuals against the development of tuberculosis but also confered a degree of herd immunity, consequently mitigating the disease's transmission across communities (Pavlinac et al., 2015). Comparatively, regions with higher BCG vaccination coverage had lower rates of tuberculosis transmission and fewer TB cases, according to a study conducted by researchers at universities in Kenya. This underscored the population-level indirect advantages of vaccination initiatives in tuberculosis prevention.

Notwithstanding the achievements of vaccination programs in mitigating the burden of tuberculosis, obstacles persisted in the realm of attaining universal coverage and efficacy of the BCG vaccine in Kenya. Regional differences in vaccine coverage and efficacy contributed to disparities in the incidence and prevalence of tuberculosis (Orege et al., 1993). In addition, the emergence of drug-resistant strains of tuberculosis undermined the necessity for continued investment in research and development of novel TB vaccines with enhanced coverage and efficacy, thereby posing a threat to TB control efforts (Orege et al., 1993). Enhanced healthcare infrastructure and broader accessibility to tuberculosis diagnosis and treatment services were further integral elements of all-encompassing tuberculosis control strategies in Kenya.

As a result of vaccination programs, specifically the distribution of the BCG vaccine, substantial progress had been achieved in Kenya regarding the prevention of tuberculosis. The substantial rates of BCG vaccination uptake among neonates had played a role in the decline of tuberculosis incidence, particularly among children, and have also exerted a more extensive influence on the transmission of TB within communities (Bates et al., 2015). Nevertheless, persistent endeavors were required to confront obstacles including inequities in vaccine coverage and the proliferation of drug-resistant strains of tuberculosis. Kenyas were able to further advance the eradication of tuberculosis as a public health menace by placing emphasis on vaccination initiatives and fortifying TB control strategies.

D. The Impact of Vaccination Programs on the Prevention of Infectious Diseases Tuberculosis in Uganda

Uganda was ranked as one of the thirty nations that the World Health Organization had identified as having a high burden of tuberculosis and HIV. In 2019, it was estimated that the incidence rate of tuberculosis was 200 per 100,000 people, while the mortality rate was 35 per 100,000 people. 65,897 cases of tuberculosis were reported in 2019 (Lukoye et al., 2023). In the same year, the World Health Organization (WHO) assessed that 1% of newly diagnosed cases and 12% of those that had been treated in the past were cases of multidrug-resistant tuberculosis (MDR/RR-TB). The therapy of MDR/RR-TB was commenced in 384 individuals in 2017, and of those patients, 74% were effectively treated against the disease (Lukoye et al., 2023).

For the purpose of addressing the burden of tuberculosis in the country, the Ministry of Health (MoH) established a comprehensive TB and Leprosy Strategic Plan for the years 2020/21-2024/25. This plan places an emphasis, among other treatments, on patient care (Lukoye et al., 2023). In connection to the strategic direction, global evidence, and high-level advocacy, the strategy highlights the current implementation state of the country's response to tuberculosis (TB) (Lutwama et al., 2014).

Uganda's attempts to eradicate tuberculosis (TB) involve working together with other stakeholders and engaging in multi-stakeholder partnerships in order to speed up the implementation of TB control measures (Stein et al., 2018). This partnership led to the establishment of a multi-drug resistant tuberculosis (MDR-TB) treatment center at the headquarters of the Uganda Prisons Service by the Centers for Disease Control and Prevention (CDC) in the United States of America. In Uganda, this clinic is the only referral and management center for patients who are incarcerated and have multidrug-resistant tuberculosis.

WHO coordinated partners to design and carry out a Mid-Term Review of the National Strategic design for TB and Leprosy Control 2020/21-2024/25 (TB NSP MTR) in order to determine the progress that has been made and the problems that have been encountered during the implementation process. This review was carried out with the help of the Ministry of Health (Stein et al., 2018).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

Using the procedures that were suggested by the World Health Organization and defined in the most recent version of the TB Review Guidelines, an internal desk Mid-Term Review of the National Strategic Plan for TB and Leprosy Control 2020/21-2024/25 (TB NSP MTR) was carried out in December 2022. This review evaluated the progress that had been made in the midterm execution of the plan. A group of internal and external reviewers from the Ministry of Health, the World Health Organization, the United States Agency for International Development (USAID), the Global Fund, the Centers for Disease Control and Prevention (CDC), the Stop TB Partnership (STP), and academic institutions carried out this review in April of 2023 (Lukoye et al., 2023).

E. The Impact of Vaccination Programs on the Prevention of Infectious Diseases Tuberculosis in South Africa

South Africa has one of the world's highest tuberculosis (TB) burdens, making it a major public health concern. The country's TB preventive and control efforts have been greatly influenced by vaccination programs, especially the Bacille Calmette-Guérin (BCG) vaccine (Dania et al., 2023). In order to prevent serious cases of tuberculosis, such as TB meningitis and disseminated TB in children, the BCG vaccination was given to babies in South Africa as part of their regular immunization program. There had been a decrease in tuberculosis (TB) incidence rates among this susceptible demographic, according to data from the South African Department of Health, which showed that the BCG vaccine was highly covered among newborns (Dania et al., 2023).

Additionally, vaccination efforts had been essential in lowering the prevalence and transmission of tuberculosis (TB) in South Africa's population. There were fewer tuberculosis cases and lower rates of tuberculosis transmission in regions where the BCG vaccine was more widely used, according to studies. A study carried out by academics from universities in South Africa demonstrated that the BCG vaccine had direct protective benefits, reducing the likelihood of tuberculosis infection and its progression to active TB disease in vaccinated persons (Jassat et al., 2021). Also, the BCG vaccine could lessen the overall impact of tuberculosis in communities by creating herd immunity.

Challenges remained in reaching universal coverage and ensuring the efficacy of the BCG vaccine in South Africa, notwithstanding the success of vaccination campaigns. Incidence and prevalence of tuberculosis (TB) varried across the nation due to differences in healthcare availability and vaccination rates. An further concern for tuberculosis control initiatives in South Africa was the rise of drug-resistant TB strains, especially MDR-TB and XDR-TB. To overcome these obstacles, it was necessary to construct thorough tuberculosis control measures, improve healthcare infrastructure, and increase access to tuberculosis diagnosis and treatment (Peltzer & Louw, 2014).

By 2030, South Africa had committed to reducing the number of new cases of tuberculosis by 80 percent compared to the levels in 2015. According to the most recent data from the World Health Organization (WHO), the number of persons in South Africa who became infected with tuberculosis in 2022 was 280 000, which was a decrease from the 552 000 cases that were reported in 2015. There had also been a decrease in the number of tuberculosis cases per 100,000 individuals. As of 2022, 468 out of every 100,000 persons residing in South Africa were diagnosed with tuberculosis, which was a significant decrease from the 988 cases that were reported in 2015. In terms of the World Health Organization's milestone targets, this amounts to a 53% reduction in the incidence of tuberculosis between the years 2015 and 2030. This puts the country in a strong position to accomplish the Sustainable Development Goal aim of reducing the incidence of tuberculosis by 80% by the year 2030 (Peltzer & Louw, 2014).

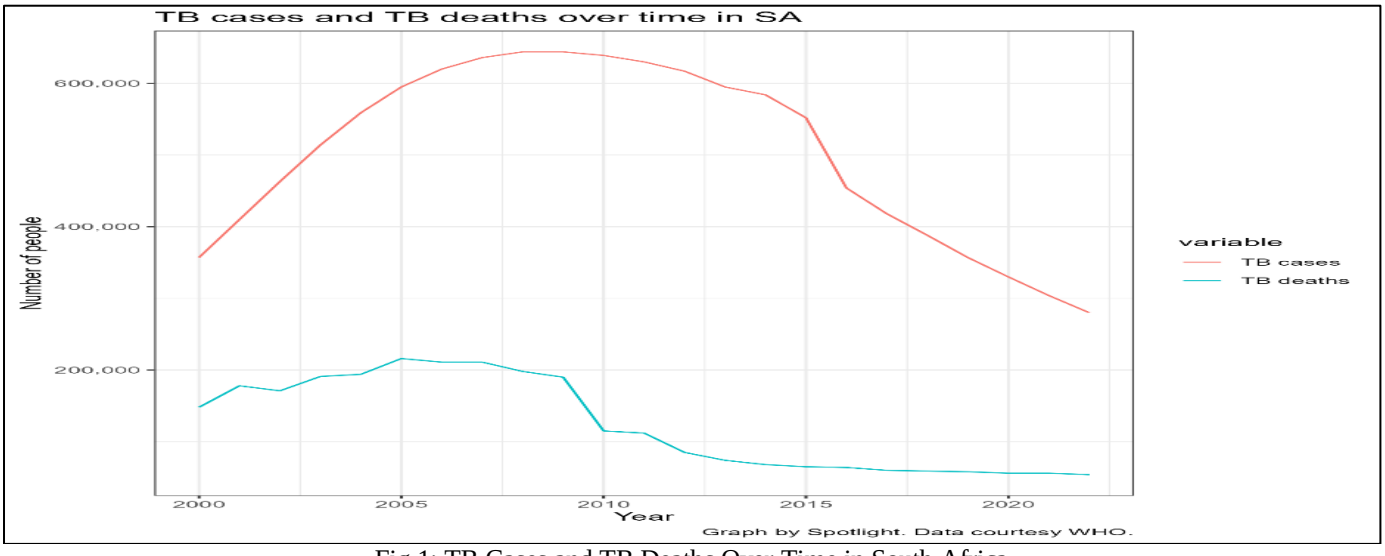

Fig 1: TB Cases and TB Deaths Over Time in South Africa

Countries made a commitment to increase the number of people receiving tuberculosis preventative therapy to 90 percent of those who were at a high risk of contracting tuberculosis during the United Nations High-Level Meeting on Tuberculosis in 2023 (Zhang & Liu, 2023). This included household contacts of people who have tuberculosis (including children) and persons who were

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living with HIV. The treatment for tuberculosis prevention normally consists of a series of medications that were taken for a period of three to six months (Hippner et al., 2019).

In South Africa, the number of persons who began preventive therapy in 2022 was 305 350, which was 5.6% less than the number of people who began preventive therapy in 2021, which was 321 610 (Hippner et al., 2019). When it came to providing children who were living with someone who had tuberculosis with the medicines, the government was doing a better job of providing preventive therapy to persons who have HIV than it was at providing the medications to their parents. In 2022, it was anticipated that 62% of people who had just registered in HIV care were started on preventative medicine, whereas only 45% of children who were living with someone who had tuberculosis initiated treatment (Peltzer & Louw, 2014).

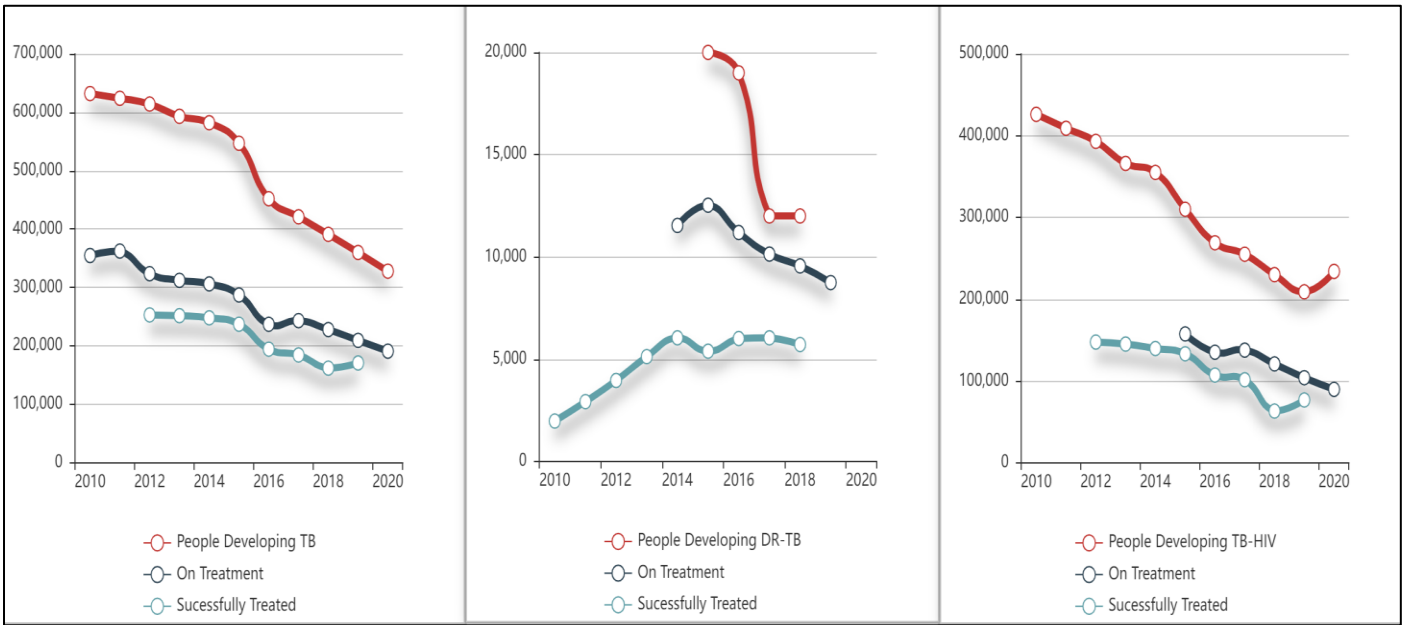

Fig 2: Analysis of Treatment and Preventive Therapy
Source: (Peltzer & Louw, 2014)

F. The Impact of Vaccination Programs on the Prevention of Infectious Diseases Tuberculosis in Ethiopia.

The high rates of morbidity and death caused by tuberculosis (TB) continue to be a major concern in Ethiopia's public health system. Vaccination initiatives, especially the Bacille Calmette-Guérin (BCG) vaccine, had successfully reduced tuberculosis cases in the nation (Ato & Sis, 2019). As a standard component of Ethiopia's national vaccination program, the BCG vaccine was regularly given to newborns. This helped prevent tuberculosis (TB) and its more severe manifestations, including TB meningitis and disseminated TB in children. According to statistics compiled by the Ethiopian Ministry of Health, a significant decrease in tuberculosis cases had been attributable, in part, to the high rates of BCG vaccine coverage among Ethiopian infants (Ato & Sis, 2019).

Also, immunization campaigns had been very helpful in lowering tuberculosis (TB) rates in Ethiopia. There were fewer tuberculosis cases and lower rates of tuberculosis transmission in regions where the BCG vaccine was more widely used, according to studies. Researchers in Ethiopia demonstrated that BCG vaccination directly protected against tuberculosis (TB) infection and its development to active disease in a trial of vaccinated persons (Mengistu & Witbooi, 2022). Also, the BCG vaccine could lessen the overall impact of tuberculosis in communities by creating herd immunity.

There were still obstacles to attaining universal coverage and ensuring the efficacy of the BCG vaccine in Ethiopia, even though vaccination campaigns had been successful. Incidence and prevalence of tuberculosis (TB) varried across the nation due to differences in healthcare availability and vaccination rates. Another major challenge to tuberculosis (TB) control initiatives in Ethiopia was the rise of drug-resistant TB strains, especially MDR-TB and XDR-TB. To overcome these obstacles, it was necessary to construct thorough tuberculosis control measures, improve healthcare infrastructure, and increase access to tuberculosis diagnosis and treatment (Malede et al., 2019).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

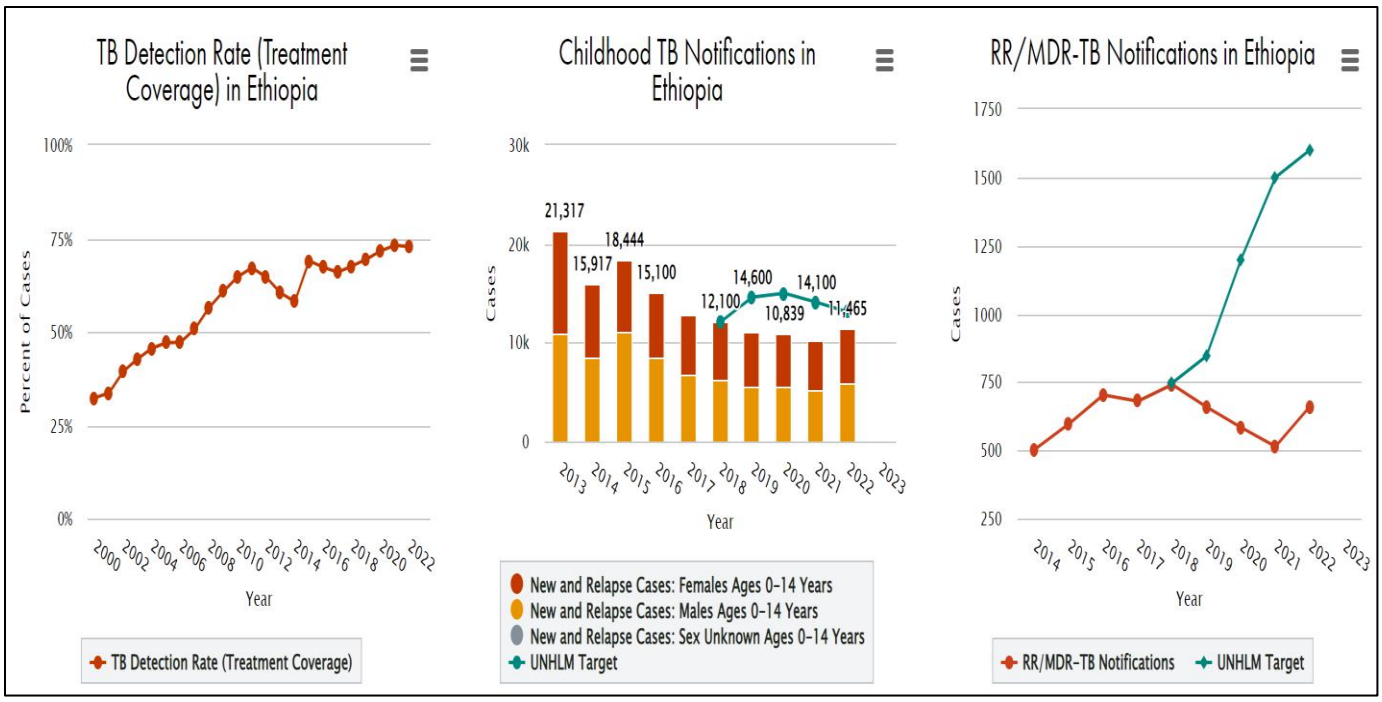

Fig 3: Vaccination Programs on the Prevention of Infectious Diseases Tuberculosis in Ethiopia
Source:(Malede et al., 2019)

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CHAPTER THREE
LITERATURE REVIEW II

A. The Analysis of the Global Burden and Approach to Tuberculosis Control

Tuberculosis (TB) has continued to be a substantial worldwide health concern, as evidenced by the annual reporting of millions of new cases and fatalities. Based on the most recent data provided by the World Health Organization (WHO), the incidence of tuberculosis was projected to affect approximately 10 million individuals in 2020, resulting in 1.5 million fatalities (World Health Organization, 2021). The urgency for global implementation of effective tuberculosis control measures was highlighted by these numbers.

An essential strategy for tuberculosis control involved the timely identification and diagnosis of the disease. Treatment could be initiated promptly when tuberculosis cases were identified in a timely manner, thereby reducing the risk of transmission and averting severe outcomes (World Health Organization, 2021). Notwithstanding these advancements, a considerable percentage of tuberculosis cases across the globe continue to go undiagnosed or receive insufficient treatment. 60% of the estimated tuberculosis cases were detected and reported in 2020, leaving a significant lacuna in efforts to identify TB cases.

TB was managed with a combination of antibiotics administered over an extended period of time. Although effective treatments were available, maintaining adherence to treatment regimens was particularly difficult in settings with limited resources (World Health Organization, 2021). Treatment interruptions or incomplete regimens contributed to the emergence of drug-resistant strains of tuberculosis, which subsequently posed greater treatment challenges and incur higher costs. An estimated 465,000 cases of rifampicin-resistant tuberculosis (a marker for multidrug-resistant TB) were reported by the World Health Organization in 2020, highlighting the increasing threat of drug resistance to TB control efforts (Wang et al., 2023) .

Vaccination and other preventative measures were vital components of tuberculosis control strategies. In many nations, infants were administered the Bacille Calmette-Guérin (BCG) vaccine, which offerred only limited protection against severe forms of tuberculosis (World Health Organization, 2021). However, there was variability in the effectiveness of the vaccine, and it failed to provide absolute protection against tuberculosis infection or impede the progression of TB disease in adults. Furthermore, certain regions continued to have limited access to tuberculosis vaccines, which exacerbated disparities in TB burden and control efforts (Dean et al., 2022).

B. The History of TB and BCG Vaccinations

Since antiquity, scientists have confirmed the existence of tuberculosis in humans. Discrete traces of the ailment have been identified in prehistoric skeletal remains. Historically, the terms "Consumption" and "Phthisis" were employed to designate tuberculosis (TB), a highly lethal disease that accounted for one in every four fatalities throughout the 19th century (Enitan et al., 2022).

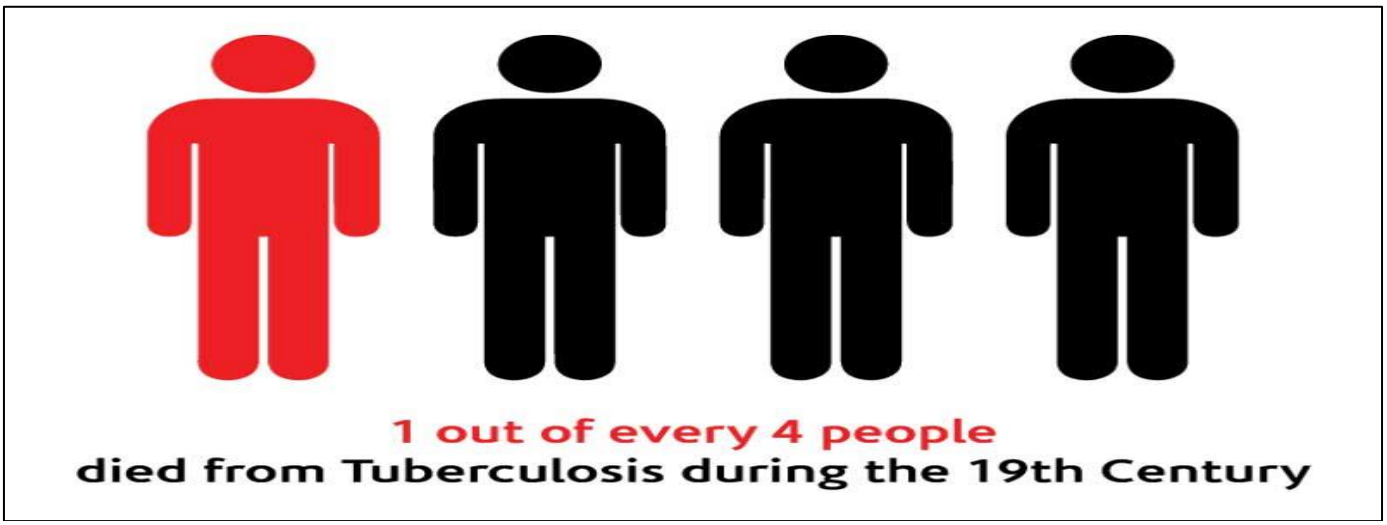

Fig 4: The History of TB and BCG Vaccinations
Source: (Enitan et al., 2022).

Assemblies predating the Industrial Revolution frequently linked tuberculosis with vampires. This belief expanded due to the health deterioration experienced by infected family members following the death of a family member from tuberculosis. People believed that the original cause was responsible for the other family members' life-threatening tuberculosis (Wang et al., 2023).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

Robert Koch was awarded the Nobel Peace Prize in 1905 for his discovery of the bacterium that causes tuberculosis in March 1882. The Bacille Calmette-Guérin (BCG) vaccination for tuberculosis, developed by Albert Calmette and Camille Guérin in 1906, marked the initial significant advancement in immunization against the disease (Arumairaj et al., 2023). Initially administered to humans in France in 1921, the BCG vaccine did not achieve widespread adoption in the United States, Great Britain, and Germany until the post–World War II era (Wang et al., 2023).

Although this vaccine offers a certain degree of protection against critical forms of non-pulmonary tuberculosis in children, such as TB meningitis, it is not dependable in preventing adult pulmonary TB, which constitutes the majority of the disease burden and global transmission of TB.

C. Global Expenditure on TB Vaccinations

Worldwide funding for tuberculosis prevention, diagnosis, treatment, and care was detailed in the World Health Organization's (WHO) yearly Global Tuberculosis Report in 2022 (WHO, 2022). Vaccination initiatives, research, and the improvement of health systems were all part of the TB control budget. The World Health Organization reported that there has been a steady increase in financing for initiatives aimed at controlling and eliminating tuberculosis (WHO, 2022).

Prevention, diagnosis, treatment, and care for tuberculosis were projected to require approximately $6.5 billion worldwide in 2020. Half of the necessary funds have been raised so far, leaving a large disparity between the two sets of needs and available resources (Bagcchi, 2023). A variety of entities, including governments, philanthropic groups, donors (both bilateral and multilateral), and others, work together to finance global tuberculosis control initiatives. Several national governments, US AID, the Bill & Melinda Gates Foundation, UNITAID, and the Global Fund to Fight AIDS, Tuberculosis and Malaria were among the most significant funders and contributors to tuberculosis control efforts (Bagcchi, 2023).

Vaccinations were an essential part of overall tuberculosis control initiatives, even if there may not be easily accessible spending data specifically for TB vaccines. To achieve global targets for tuberculosis control and elimination, it was vital to continue investing in TB vaccine programs and to implement other treatments such as enhanced diagnosis, treatment, and health system strengthening.

The research laid out the ways in which a more potent vaccine could have a greater influence. Between 2025 and 2050, a 1.5-fold increase in the effectiveness of the tuberculosis vaccination for adults and adolescents might avoid an estimated 4.6-8.5 million deaths and 37.2-76 million cases of tuberculosis. A 75% effective vaccination, on the other hand, may save 54-110 million cases of tuberculosis and 6.7-12.3 million deaths from the disease during the same time period (WHO, 2022). From an economic perspective, a vaccine that was 50% effective might prevent 36.6-41.5 billion dollars in TB-related household expenditures. This would help to avoid two thirds of the catastrophic costs that the lower wealth quintile often faces. The same vaccination had the potential to provide a boost to GDP of $1.6 trillion from 2025–2080 (Arumairaj et al., 2023).

D. The Tuberculosis Situation in African Regions

Among infectious diseases, tuberculosis (TB) ranks first and was the tenth worst killer globally. Among those living with HIV, tuberculosis was the main cause of death. Tuberculosis sickened 10.4 million individuals in 2016 (Abdullahi et al., 2019). Africa has been home to 2.5 million people, making about a quarter of the total (Cratsley & Mackey, 2018). There were 1.7 million TB-related deaths worldwide in that year, with 417,000 (or more than 25%) occurring in Africa. The detection and treatment of tuberculosis saved the lives of 10 million people in the African Region between the years 2000 and 2014 (Abdullahi et al., 2019). Sustainable Development Goals for Health include eradicating tuberculosis (TB) by 2030 as one of their health-related objectives. Goals to eradicate tuberculosis in Africa by the year 2030 were laid out in the 2013 Abuja Declaration (World Health Organization, 2010).

The tuberculosis virus spreaded through the air. Transmission of tuberculosis (TB) occurred when an infected person's cough, sneeze, or spit was inhaled into the air. When tuberculosis was active in the lungs, symptoms such as a persistent cough (often with blood in it), chest discomfort, fatigue, loss of appetite, fever, and night sweats are common (WHO, 2010).

Tuberculosis was curable and has effective treatments. Assuming appropriate treatment, the vast majority of cases are curable. Under the guidance of a healthcare professional or qualified individual, it was treated using a conventional 6-month regimen of four antimicrobial medications. The two most effective first-line anti-TB medications, isoniazid and rifampicin, were ineffective against the germs that cause multidrug-resistant tuberculosis (MDR-TB) (World Health Organization, 2010). When first-line treatments fail, second-line medications treated and even cure multidrug-resistant tuberculosis. Nevertheless, there was a lack of effective second-line treatments, and those that didn't exist necessitate costly and harmful chemotherapy that could last up to two years (Haley et al., 2021). Bacteria that developed resistance to the most powerful second-line anti-TB treatments re known as extensively drug-resistant tuberculosis (XDR-TB), and this more severe kind of multidrug-resistant tuberculosis (MDR-TB) frequently leaves patients with no other therapeutic choices. A novel medication for highly drug-resistant tuberculosis was approved by the FDA on August 14, 2019 (Haley et al., 2023).

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An ineffective tuberculosis vaccination does exist. To a lesser extent, it prevents the spread of illness. One of the most effective ways to prevent the spread of the virus was to put a stop to transmission between adults. One way to achieve this was by curing patients who had active tuberculosis. The detection of latent tuberculosis and its prevention from developing into active infectious tuberculosis was another important consideration (Cratsley & Mackey, 2018). An important part of TB prevention was infection control, which included taking measures to stop the spread of the disease in various places including hospitals. Another measure that helps keep humans safe from bovine tuberculosis was the pasteurization of milk.

E. Research Aim

➢ *Research Objective*

The primary objective of this study was to assess the outcomes and effectiveness of vaccination initiatives in Gasabo District, with a specific emphasis on the prevention of TB and other infectious diseases. By employing a case study approach, the study aim to delved into the local dynamics, challenges, and successes of the vaccination programs, providing a nuanced understanding of their impact on community health.

➢ *Research Question*

- What was the impact of vaccination programs on the prevention of infectious diseases, specifically tuberculosis (TB) and other relevant infections, in Gasabo District, Rwanda?
- How did vaccination coverage rates, historical disease prevalence, socio-economic factors, and community perceptions contribute to the overall effectiveness of vaccination initiatives in mitigating the burden of infectious diseases in the region?

F. The Research Gap

To what extent vaccination programs had been successful in lowering tuberculosis (TB) incidence in the Gasabo District of Rwanda was an important question that needed an answer in the study that evaluated the effects of such programs on the prevention of infectious diseases generally and TB in particular. Vaccination programs, such as the Bacille Calmette-Guérin (BCG) vaccine, were extensively used to combat tuberculosis (TB) worldwide. However, it was possible that disease epidemiology, vaccination coverage, and program execution varied among people and locations. When looking at variables like vaccine coverage rates, changes in tuberculosis incidence, and socio-demographic predictors of tuberculosis burden, there was a lack of data on how vaccination programs had directly affected tuberculosis prevention in Gasabo District.

In addition, it might have been necessary to investigate how well immunization programs worked in lowering tuberculosis (TB) rates among various Gasabo District demographic subgroups, including children, adolescents, adults, and at-risk groups like migrants, refugees, and people residing in urban slums. In order to enhance vaccine coverage and limit tuberculosis transmission in the community, it was important to understand how vaccination programs affectted tuberculosis prevention differently among different demographic groups. This knowledge did help to inform targeted interventions and tactics.

There was a possibility of lack of studies looking at how other TB control initiatives in Gasabo District interacted with vaccination programs, like case detection, contact tracing, and treatment adherence support. To better understand how to prevent tuberculosis (TB) in a given area, it was important to study the additive effects of vaccination programs with other TB control approaches. Improving public health outcomes and bolstering TB control efforts in Gasabo District, Rwanda, could be achieved by filling up these research gaps and implementing decisions and policies based on evidence.

G. Hypothesis

➢ *Null Hypothesis (H0)*

There was no significant impact of vaccination programs on the prevention of infectious diseases, including tuberculosis (TB), in Gasabo District, Rwanda.

➢ *Alternative Hypothesis (H1)*

Vaccination programs significantly contributed to the prevention of infectious diseases, particularly tuberculosis (TB), in Gasabo District, Rwanda.

➢ *Additional Hypotheses*

- ***H1a:*** Higher vaccination coverage rates were associated with a lower incidence of tuberculosis and other infectious diseases in Gasabo District.
- ***H1b:*** Socio-economic factors, such as income levels and education, significantly influenced the effectiveness of vaccination programs in preventing infectious diseases in Gasabo District.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

- ***H1c:*** Historical disease prevalence was negatively correlated with current vaccination coverage, suggesting that successful vaccination initiatives might have led to a decline in disease prevalence over time.
- ***H1d:*** Positive community perceptions and attitudes toward vaccination are positively associated with higher vaccination coverage rates and, consequently, a lower incidence of infectious diseases in Gasabo District.

These hypotheses formed the basis for testing the effectiveness and impact of vaccination programs on the prevention of infectious diseases, allowing for a nuanced exploration of various factors contributing to the overall success or limitations of vaccination initiatives in Gasabo District, Rwanda.

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CHAPTER FOUR
METHODOLOGY

A. The Study Design

The study design for assessing the impact of vaccination programs on the prevention of infectious diseases, specifically focusing on Gasabo District in Rwanda, was retrospective cohort study. This study design involved collecting data from existing records and databases to assess the vaccination status of individuals within the district and then tracking their incidence of infectious diseases over time. By comparing the incidence rates of infectious diseases between vaccinated and unvaccinated individuals, the study can evaluate the effectiveness of vaccination programs in preventing tuberculosis diseases.

- *The Study Technique*

The study applied the use of systematic random sampling technique. Systematic random sampling involved selecting study participants at regular intervals from a list or sampling frame of the target population. This method ensured that every individual in the population had an equal chance of being selected, while also providing a straightforward and systematic approach to sampling.

As for the case of assessing vaccination programs, systematic random sampling allowed the researcher to obtain a representative sample of individuals who had received vaccinations within Gasabo District. By systematically selecting individuals from vaccination records or other relevant databases, and available hospital health records which made the researcher to ensure that the sample accurately reflected the diversity of the vaccinated population in the district.

Furthermore, systematic random sampling helped to minimize selection bias and ensured that the sample was representative of the broader population, increasing the generalizability of the study findings. This approach was particularly important for retrospective cohort studies, where the researcher relied on existing data and ensured that the sample accurately represents the population of interest.

B. Retrospective Study Design Implications

The utilization of this study design enabled the researcher to effectively gather data on exposure (vaccination status) and outcome (incidence of infectious diseases) by utilizing pre-existing data sources, such as vaccination records and disease surveillance databases, thereby eliminating the necessity for prospective data collection. The utilization of retrospective data enables researchers to address logistical and resource limitations commonly encountered in prospective cohort studies, hence enhancing the feasibility and cost-effectiveness of the project.

Furthermore, the utilization of a retrospective cohort study allowed researcher to demonstrate temporal associations between vaccination status and disease outcomes through the analysis of historical data. The utilization of a longitudinal methodology enabled the evaluation of the enduring impacts of vaccination on the prevention of diseases among the inhabitants of Gasabo District over a designated duration. The researcher had the ability to establish causality and measure the efficacy of vaccination programs in mitigating the impact of infectious diseases by monitoring people' vaccination status and subsequent disease occurrence.

Moreover, the utilization of a retrospective cohort study design enabled the ability to identify potential confounding variables and mitigate biases that could have impaced the association between vaccination and disease outcomes. To enhance the validity of study findings, the researcher had the ability to account for demographic characteristics, socioeconomic position, healthcare access, and other pertinent confounders, thereby reducing the potential for bias. This methodology enabled a more comprehensive examination of the actual influence of vaccination initiatives on the prevention of disease TB, while also considering any confounding factors that could introduce bias into the observed correlation.

Finally, the results obtained from a retrospective cohort study conducted in Gasabo District had the potential to offer significant insights and contributed to evidence-based decision-making in the realm of public health policy and the implementation of immunization programs. Policymakers and healthcare authorities will be able to enhance resource allocation, bolster vaccination strategies, and implement targeted interventions to optimize health benefits for the population of Gasabo District and beyond by showcasing the efficacy of vaccination in preventing infectious diseases at the local level. In general, the retrospective cohort research design presents a robust and enlightening methodology for assessing the effects of immunization programs on disease prevention within the particular setting of Gasabo District in Rwanda.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

C. The Background Information and Study Site Location

➢ *Background Information*

Gasabo District usually an administrative district situated within the Kigali Province of Rwanda. The region located in the center region of the nation and exhibits a heterogeneous populace, encompassing both urban and rural settlements. The Gasabo District comprised a diverse range of residential, commercial, and industrial zones, experiencing an increase in population as a result of urbanization and economic progress. The region has been renowned for its dynamic cultural legacy, esteemed educational establishments, and comprehensive healthcare infrastructure, rendering it a significant center for social and economic endeavors inside Rwanda.

➢ *Study Site Location*

The study site for evaluating the influence of vaccination programs on the prevention of infectious diseases in Gasabo District included multiple sub-districts and neighborhoods within the administrative boundaries of Gasabo District. The aforementioned entities encompassed urban hubs such as Kimironko, Gisozi, and Kacyiru, among rural regions and peri-urban communities. The factors taken into account when choosing study sites in Gasabo District were population density, availability of healthcare services, and the inclusion of individuals from various socio-economic situations within the district.

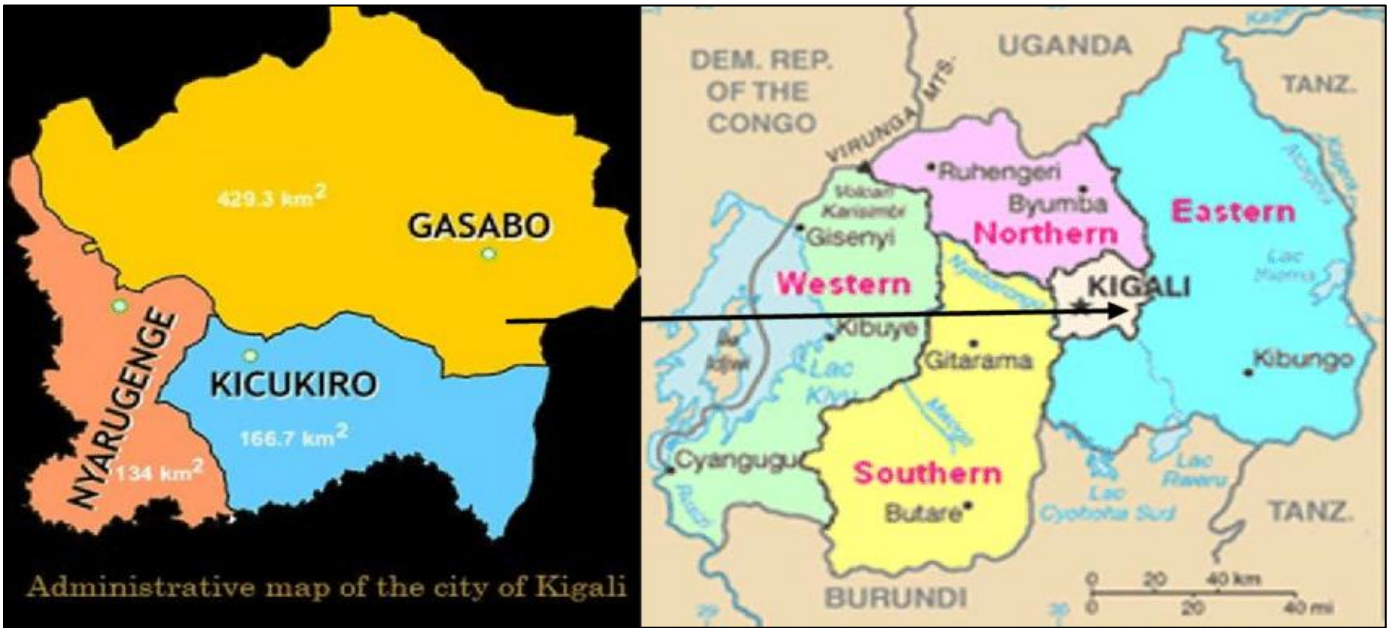

Fig 5: The Geopraphical Location of Gasabo District

Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FThe-political-and-Administrative-map-of-City-of-

Name	Status	Population Census 2002-08-16	Population Census 2012-08-15	Population Census 2022-08-15
Gasabo	District	320,516	529,561	879,505

Gasabo

879,505 Population [2022] – *Census*

429.2 km² Area

2,049/km² Population Density [2022]

5.2% Annual Population Change [2012 → 2022]

Fig 6: The Demographic Data of Gasabo District

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The study was conducted in Gasabo District, which was considered an optimal location due to its heterogeneous population, robust healthcare infrastructure, and the presence of extensive vaccination initiatives implemented by the Rwandan Ministry of Health. The strategic positioning of the district within Rwanda enabled convenient connectivity to transportation networks, hence facilitating the gathering of data and fostering engagement with local health authorities and community partners. This study was to investigate the efficacy of vaccination programs in preventing infectious diseases like TB within the Gasabo District, with the objective of providing significant insights. The findings of this research will contribute to evidence-based decision-making and public health initiatives in Rwanda.

D. Target Population

The study aimed to evaluate the effects of vaccination programs on the prevention of infectious diseases in Gasabo District, Rwanda. The target population for this research consisted of individuals who live within the district's geographical boundaries. The population encompassed individuals residing in both urban and rural areas, spanning various age cohorts ranging from infants to the elderly. These individuals met the eligibility criteria for vaccination as outlined in the national immunization schedule advocated by the Rwandan Ministry of Health.

- *The Target Population is Comprised of:*

Infants and children referred to those who meet the criteria for receiving standard childhood immunizations, such as the Bacille Calmette-Guérin (BCG) vaccine, measles vaccine, polio vaccine, and other vaccines that were indicated for the protection of infectious diseases in early childhood.

Individuals who met the criteria for receiving additional doses of vaccines, including tetanus toxoid, human papillomavirus (HPV) vaccine for the prevention of cervical cancer, and influenza vaccine for the prevention of seasonal flu, as well as targeted vaccines for specific high-risk populations such as healthcare workers and travelers.

The elderly population refers to those who are eligible for immunizations specifically indicated for older adults. These vaccines included the pneumococcal vaccine, which helped prevent respiratory infections, and the shingles vaccine, which helped to prevent herpes zoster.

Vulnerable populations encompassed individuals who possessed pre-existing health disorders, individuals with impaired immune systems, pregnant women, and other high-risk cohorts that necessitated supplementary or specialized vaccines for the purpose of disease prevention and management.

The target group comprised a heterogeneous array of socio-demographic attributes, encompassing various educational attainment, income levels, occupational backgrounds, and healthcare accessibility.

The study seeked to offer comprehensive insights into the effects of vaccination programs on the prevention of infectious diseases in Gasabo District. This was achieved by incorporating a diverse range of individuals from various age groups and demographic profiles. The ultimate goal was to provide evidence-based strategies for enhancing vaccination coverage and improving public health outcomes in Rwanda.

E. The Study Duration

The study had a time frame of six months, specifically from October 1, 2023, to March 31, 2024. This duration allowed for a full evaluation of the effects of vaccination programs on the prevention of infectious diseases in Gasabo District, Rwanda. Commencing in October, the research aligned with the shift from the rainy season to the arid season in Rwanda, providing valuable understanding of how seasonal fluctuations in weather might have impacted the spread of diseases and the behavior of seeking treatment. The study included the latter part of the dry season, which extended until March. This allowed researchers to observe any changes in vaccine coverage and disease incidence during this period of lower disease transmission.

The study's duration of six months allowed researchers to have sufficient time to investigate both immediate patterns and enduring effects of vaccination programs on the prevention of infectious diseases. The prolonged duration of this study enabled the assessment of fluctuations in vaccination coverage rates, illness incidence, and other pertinent indicators over a period of time, hence facilitating a more comprehensive comprehension of the efficacy of immunization initiatives in Gasabo District. Moreover, the length of the study period allowed researchers to considered any confounding variables and make necessary adjustments for changes in healthcare delivery, public health interventions, and socio-economic factors that could have impacted the results of the study.

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F. Sampling and Sample Size Determination

In a prevalence investigation, the appropriate sample size was determined using the subsequent straightforward method: $n = Z^2P(1-P)d^2$ proved to be the formula. The following variables comprised the equation: n denoted the sample size, Z signified the statistic corresponding to the desired level of confidence, and P signified the anticipated prevalence, which was calculated using data from a pilot study or prior research. In order to maximize variance and optimize sample size, Taherdoost (2017) recommended that researchers should refrain from utilizing more than half of the population as their hypothesis P. A closer representation of the target population was obtained by maximizing the sample size. In light of this, a minimum sample size of 500 participants was required for the study with a 5% level of significance, assuming a 10% attrition rate and a p-value of 0.05.

G. Data Collection Instrument

The study evaluating the effectiveness of vaccination programs in Gasabo District, Rwanda, utilizes a data collection instrument that pulled and extracted pertinent information from pre-existing databases, reports, and documents. This process ensured that secondary data sources were obtained in a systematic manner. Administrative datasets managed by the Rwandan Ministry of Health and other pertinent organizations were encompassed within this collection, along with national immunization registries and healthcare facility records. By employing standardized protocols and classification schemes, the desired data variables were identified and extracted, including but not limited to vaccination coverage rates, disease incidence, healthcare utilization patterns, and socio-demographic indicators. To ensure that the gathered data was accurate, comprehensive, and dependable, quality assurance procedures were executed, including data validation and verification. In order to ensure the privacy and confidentiality of individuals' information, data collection protocols were further subject to ethical guidelines and data protection regulations.

➢ *The Steps of Data Collection Instrument*

The data collection instrument involved accessing existing datasets or records rather than directly collecting data from individuals. This approach typically involved several steps to ensure data quality and reliability.

Firstly, the study researcher needed to identify and select appropriate secondary data sources that contained relevant information on vaccination programs, disease incidence, demographic characteristics, and other variables of interest. This included national or regional health databases, vaccination registries, hospital records, or surveillance systems. Once the data sources were identified, the researcher obtained permission and access to the data, ensuring compliance with ethical and legal requirements regarding data privacy and confidentiality.

After gaining access to the secondary data sources, the next step involved data extraction and validation. The researcher extracted relevant variables and records from the datasets, ensuring that the selected data aligned with the research objectives and hypotheses. During this process, it was essential to assess the quality and completeness of the data to identify any errors, inconsistencies, or missing values. Data validation techniques, such as cross-referencing with multiple sources or conducting data audits, was employed to enhance data quality and accuracy.

Once the data were extracted and validated, the researcher proceeded with data cleaning and preparation. This involved standardizing variable formats, resolving discrepancies, and addressing missing or incomplete data through imputation or exclusion. Quality control measures, such as double data entry and validation checks, were implemented to minimize errors and ensure data accuracy. Additionally, the study conducted exploratory data analysis to identify patterns, trends, or outliers that may have warranted further investigation.

H. Data Management and Analysis

Qualitative data was condensed using proportions. This was to find out whether there was a connection between the quantitative independent research variables and the dependent qualitative study variables, the chi-square test was used. All analysed using a given variable removed participants who did not supply a response for that variable. A significance level of 5% was used to conduct the statistical tests. The researcher used STATA, SPSS and the Excel program to analyze the data. Statistical analyses, including one-way ANOVA and logistic regression, revealed statistically significant relationships. In the qualitative phase, the study looked at the elements impacting the outcome from a qualitative perspective by conducting in-depth interviews with selected participants. The personal experiences, barriers, and facilitators that impacted vaccine decisions were illuminated by the tales participants shared. Through the use of thematic analysis, one to gain a deeper understanding of the building blocks by exposing previously unseen insights.

I. Ethical Framework

The study measured the effectiveness of vaccination programs in preventing infectious diseases in Gasabo District, Rwanda. It followed an ethical framework that protected the rights, welfare, and dignity of participants. Respect for autonomy, beneficence, non-maleficence, and justice were some of the well-established ethical principles that served as the bedrock of any decent ethical system. In order to ensure that all participants were fully aware of the study's goals, methods, risks, and benefits before they willingly agree to take part, informed consent was sought before any data was collected.

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Allowing participants to discontinue participation in the study at any moment without penalty was another way to respect their liberty. Aiming to advance knowledge and improve public health outcomes, studies were meticulously planned, data was collected in a way that minimized damage and maximized benefits to participants. The results were then disseminated.

Second, the ethical framework did take equity, justice, and inclusivity into account, especially when it came to distributing the research's benefits and costs fairly. The inclusion of underprivileged communities, children, and the elderly was of utmost importance in order to guarantee that their interests were appropriately represented and that their views were heard. Additionally, measures were taken to rectify any possible power disparities or conflicts of interest that may emerge throughout the course of the research, encouraging openness, responsibility, and confidence among all parties involved. In order to address health inequalities and inequities in a fair and equitable manner, the ethical framework placed a premium on sharing research results with the appropriate parties, such as community members, healthcare professionals, and lawmakers.

And lastly, the ethical framework stressed that the research project must be conducted with honesty, integrity, and responsibility at all times. Researchers upheld the utmost standards of honesty and scientific rigor by adhering to professional ethics and rules of behavior. Institutional review boards and ethical review committees were also put in place to ensure the safety and rights of study participants by independently evaluating and approving research protocols. Therefore, a responsible research, increased public faith in science, and more ethical leadership in the quest for knowledge and the betterment of society were all outcomes of this study's adherence to ethical principles and ideals.

J. The Inclusion and Exclusion Criteria

➢ *Inclusion Criteria*

- *Residence in Gasabo District:* Participants must reside within the administrative boundaries of Gasabo District to ensure relevance and applicability of study findings to the local population.
- *Age:* Individuals of all age groups, from infants to the elderly, **we**re included to capture a comprehensive understanding of vaccination uptake and disease prevention across different demographic segments.
- *Vaccination Status:* Participants m**ay have** include**d** both vaccinated and unvaccinated individuals to assess the impact of vaccination programs on disease prevention, with a focus on individuals eligible for routine vaccinations as per the national immunization schedule.
- *Willingness to Participate:* Individuals who provide**d** informed consent and express willingness to participate in the study **we**re included, ensuring voluntary participation and respect for autonomy.

➢ *Exclusion Criteria*

- *Non-residents of Gasabo District:* Individuals residing outside the boundaries of Gasabo District **we**re excluded to maintain the study's focus on the local population and ensure the relevance of findings to the study context.
- *Inability to Provide Informed Consent:* Individuals who **we**re unable to provide informed consent due to cognitive impairments, language barriers, or other reasons that compromise**d** their ability to understand the study's purpose, procedures, risks, and benefits **we**re excluded to uphold ethical principles of autonomy and respect for persons.
- *Incomplete Vaccination Records:* Participants with incomplete or unreliable vaccination records that hinder**ed** accurate assessment of vaccination status **we**re excluded to ensure the integrity and validity of study findings.
- *Individuals with Severe Health Conditions:* Individuals with severe acute or chronic health conditions that may **have** confound**ed** the relationship between vaccination status and disease prevention outcomes **we**re excluded to minimize potential biases and ensure the clarity of study results.

K. The Conceptual Framework

The conceptual framework outlined the theoretical underpinnings and logical connections between key variables or concepts in a research study. For the case of TB vaccination and vaccination response, the conceptual framework illustrated how TB vaccination directly lead to a complete vaccine status, which in turn influences vaccination response. Firstly, TB vaccination, typically through the Bacille Calmette-Guérin (BCG) vaccine, introduced antigens derived from Mycobacterium tuberculosis, the bacteria causing TB, into the body. These antigens stimulated the immune system to produce a specific immune response against TB.

Secondly, the immune response triggered by TB vaccination lead to the development of immunity against TB infection. This process involved the activation of various immune cells, such as T cells and B cells, which produce antibodies and memory cells targeted against TB bacteria. Finally, achieving a complete vaccine status, which referred to receiving the recommended doses of the TB vaccine according to the vaccination schedule, was essential for ensuring optimal immunity and vaccination response. Complete vaccine status ensured that individuals receive the full course of TB vaccination, allowing for sufficient antigen exposure and immune stimulation to generate a robust and lasting immune response against TB.

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Predisposing factors were characteristics that exist prior to the decision to seek vaccination and could influence an individual's propensity towards immunization. Age and gender were key predisposing factors, as vaccination recommendations often vary based on age and gender-specific vulnerabilities. Additionally, level of education played a role in shaping attitudes and knowledge about vaccination, with higher education levels typically associated with greater awareness and uptake. Vaccination status and knowledge about vaccination reflect prior experiences and understanding, which can influence future decisions. Co-admission knowledge pertains to understanding the simultaneous administration of multiple vaccines, which can impact vaccination acceptance.

Enabling factors encompass conditions that facilitate or hindered access to vaccination services. Place of residence and distance to healthcare facilities determine physical accessibility, with rural or remote areas often facing greater challenges in reaching vaccination centers. Access to health facilities, influenced by infrastructure and transportation, was crucial for vaccine delivery. Socio-economic determinants, such as income and employment status, influence affordability and availability of healthcare services. Awareness of vaccination benefits, including understanding the importance of immunization for disease prevention, can motivate individuals to seek vaccination.

Need factors related to perceived or evaluated healthcare needs that prompt individuals to seek vaccination. Antenatal and postnatal care provided opportunities for integrating vaccination services into maternal and child health programs. Follow-up on vaccinations ensures completion of recommended vaccine schedules. Community health workers (CHWs) and healthcare workers (HCWs) played vital roles in delivering vaccinations and educating communities. Tuberculosis (TB) diagnosis methods may have prompted vaccination efforts, especially among high-risk groups. Targeted groups, such as pregnant women, children, and immunocompromised individuals like people living with HIV (PLWHIV), have specific vaccination needs. Treatment regimens, particularly for diseases like TB, may necessitate vaccination strategies to prevent complications and co-infections.

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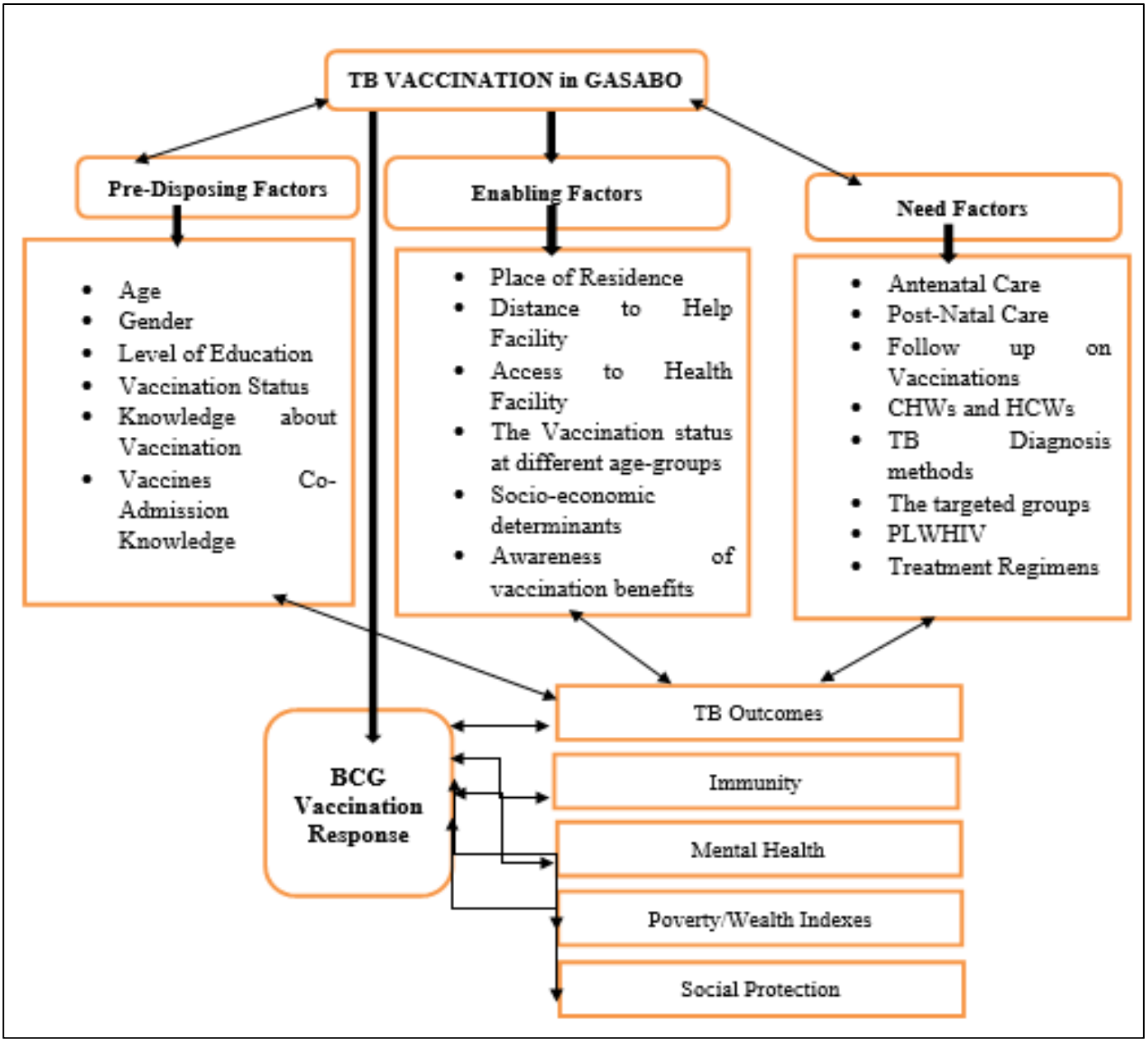

Fig 7: The Conceptual Framework

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CHAPTER FIVE
FINDINGS / ANALYSIS /DISCUSSION

A. The Descriptive Statistics

From the data sources, the were a total of 152,573 males and 144,195 females. According the National Demographic survey of 2022, Rwanda, Gasabo District has a population of 879,505. This represented 33.74% of the general population. Descriptive statistics included a range of key variables such as TB incidence rates, vaccination coverage, and socio-economic indicators. These statistics provided a snapshot of the distribution and variability of these variables within the population, helping the researcher to understand the magnitude and spread of TB, the effectiveness of vaccination programs, and the socio-economic context of TB prevention efforts. Descriptive statistics played a crucial role in summarizing data, identifying trends, and informing further analyses and interventions aimed at reducing TB burden and improving public health outcomes in Gasabo District.

Table 1: The Descriptive Statistics of Gender

GENDER	Males (n)	Females (n)
	152,573	144,195

B. Suceptibility of TB infection Between Vaccinated Males and Females

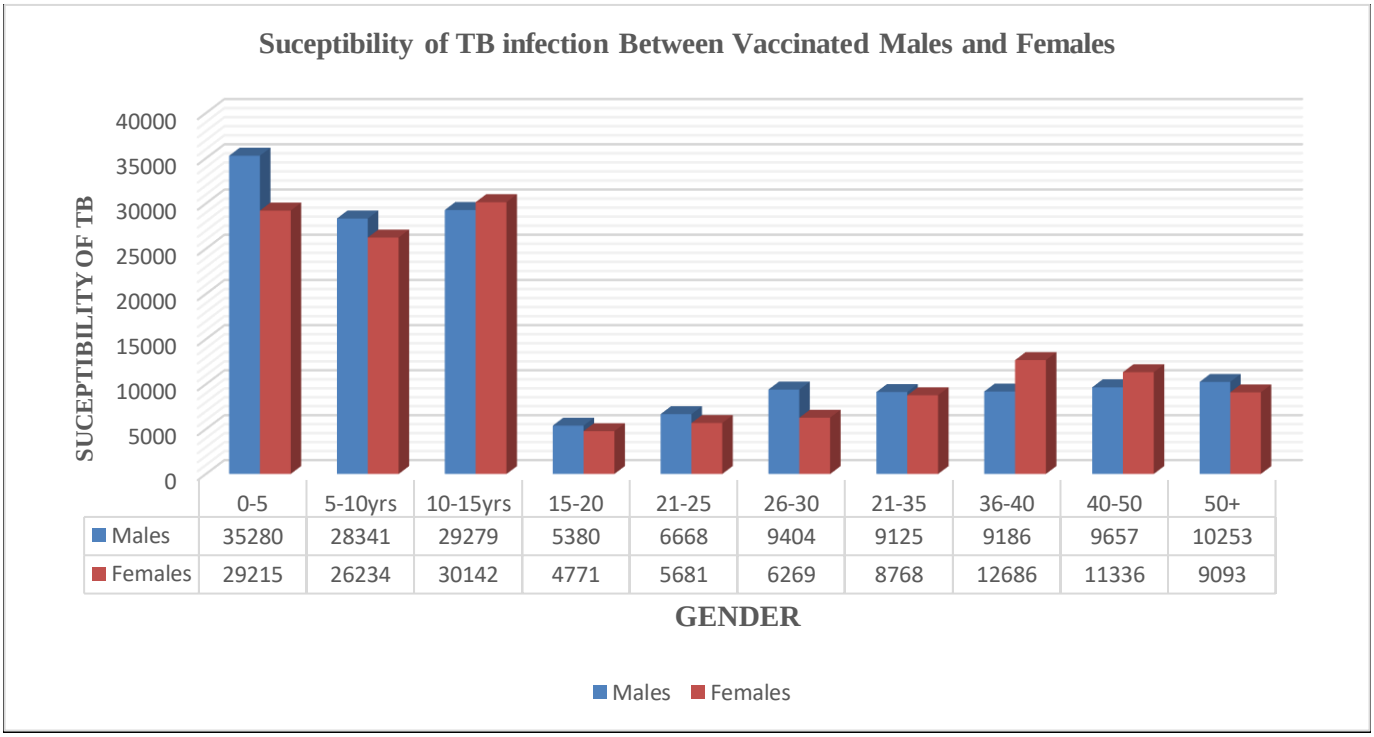

Fig 8: Suceptibility of TB infection Between Vaccinated Males and Females

➢ *Analysis*

By analyzing the vaccination coverage data, the study gained insights into the potential impact of TB vaccination on susceptibility to TB infection among males and females in Gasabo District.

Firstly, the data revealed varying TB vaccination coverage levels among different age groups and genders. Among males, the highest vaccination coverage was observed in the 0-5 age category, with 35,280 individuals vaccinated, followed by a gradual decline in vaccination coverage in older age groups. Similarly, females exhibited a similar pattern, with the highest vaccination coverage also observed in the 0-5 age category, albeit with slightly lower numbers compared to males. This suggested a proactive approach to TB vaccination during early childhood, aiming to provide protection against TB infection from a young age.

Furthermore, while vaccination coverage generally decreases with increasing age among both males and females, there were notable differences in vaccination coverage between genders within certain age groups. For instance, in the 36-40 age category, females exhibited higher vaccination coverage compared to males, with 12,686 females vaccinated compared to 9,186 males. This difference reflected variations in healthcare-seeking behaviors, access to vaccination services, or other socio-demographic factors between genders within this age group.

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C. Assessment of Vaccination Coverage Rates among Different Population Groups

➢ *Infants and Children*

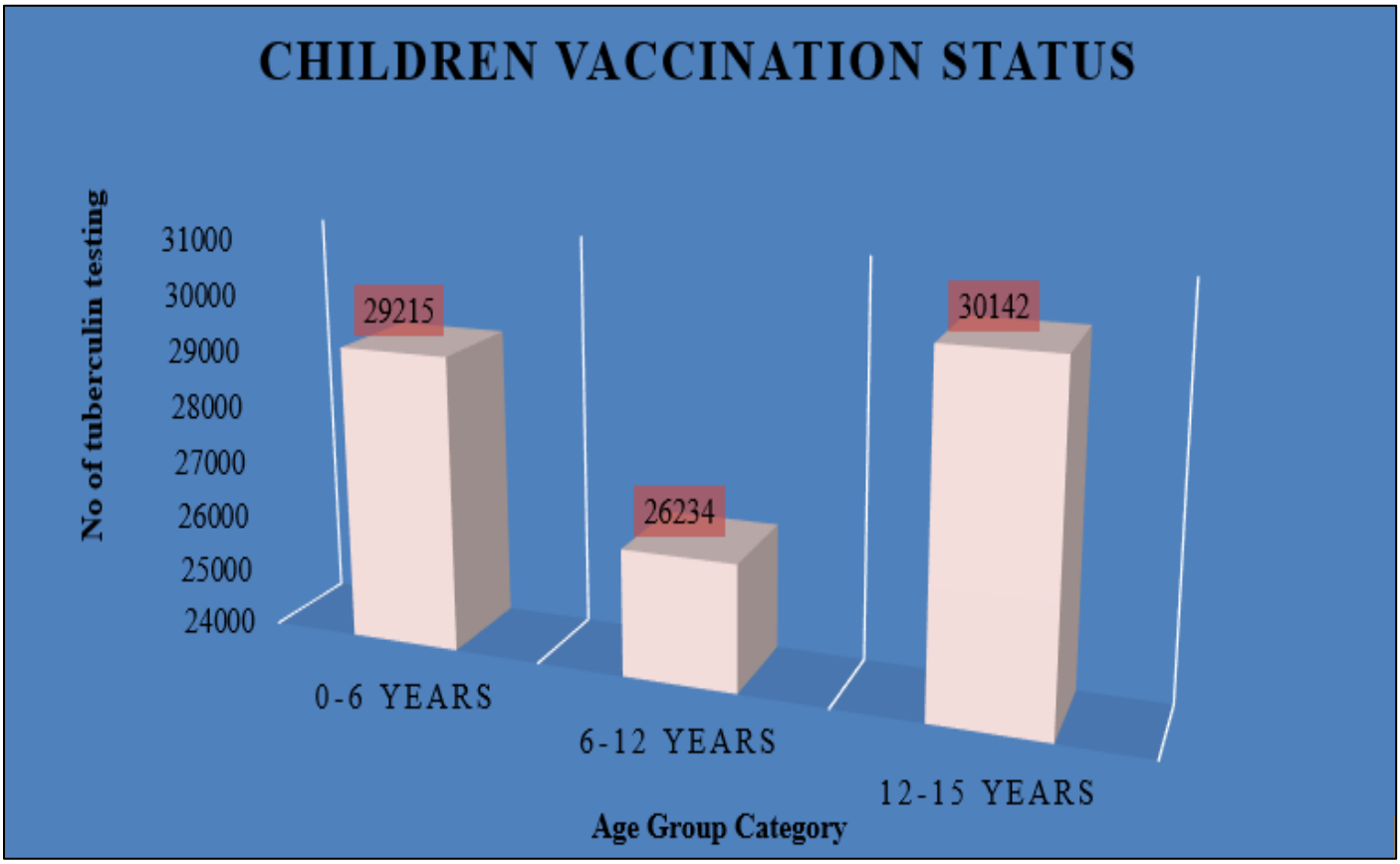

Fig 9: Children Vaccination Status

➢ *Analysis*

The provided data presented the vaccination status of children in Gasabo District across different age groups, categorized by gender. Analyzing the vaccination coverage data provided insights into the TB vaccination efforts targeting children, a critical population for preventive healthcare interventions.

Among children aged 0-6 years, both males and females showed relatively high vaccination coverage, with 35,280 males and 29,215 females vaccinated. This suggests a proactive approach to TB vaccination during early childhood, aligning with global recommendations to prioritize vaccination at a young age to provide early protection against TB infection.

In the 6-12 years age group, vaccination coverage remained high but showed a slight decrease compared to the 0-6 years age group, with 28,341 males and 26,234 females vaccinated. Despite this decrease, the vaccination coverage remained substantial, indicating continued efforts to maintain vaccination coverage among school-aged children, a key demographic for TB prevention.

In the 12-15 years age group, vaccination coverage levels were relatively consistent between males and females, with 29,279 males and 30,142 females vaccinated. This suggested ongoing vaccination efforts targeting adolescents, a critical age group for TB prevention due to increased social interactions and potential exposure to TB.

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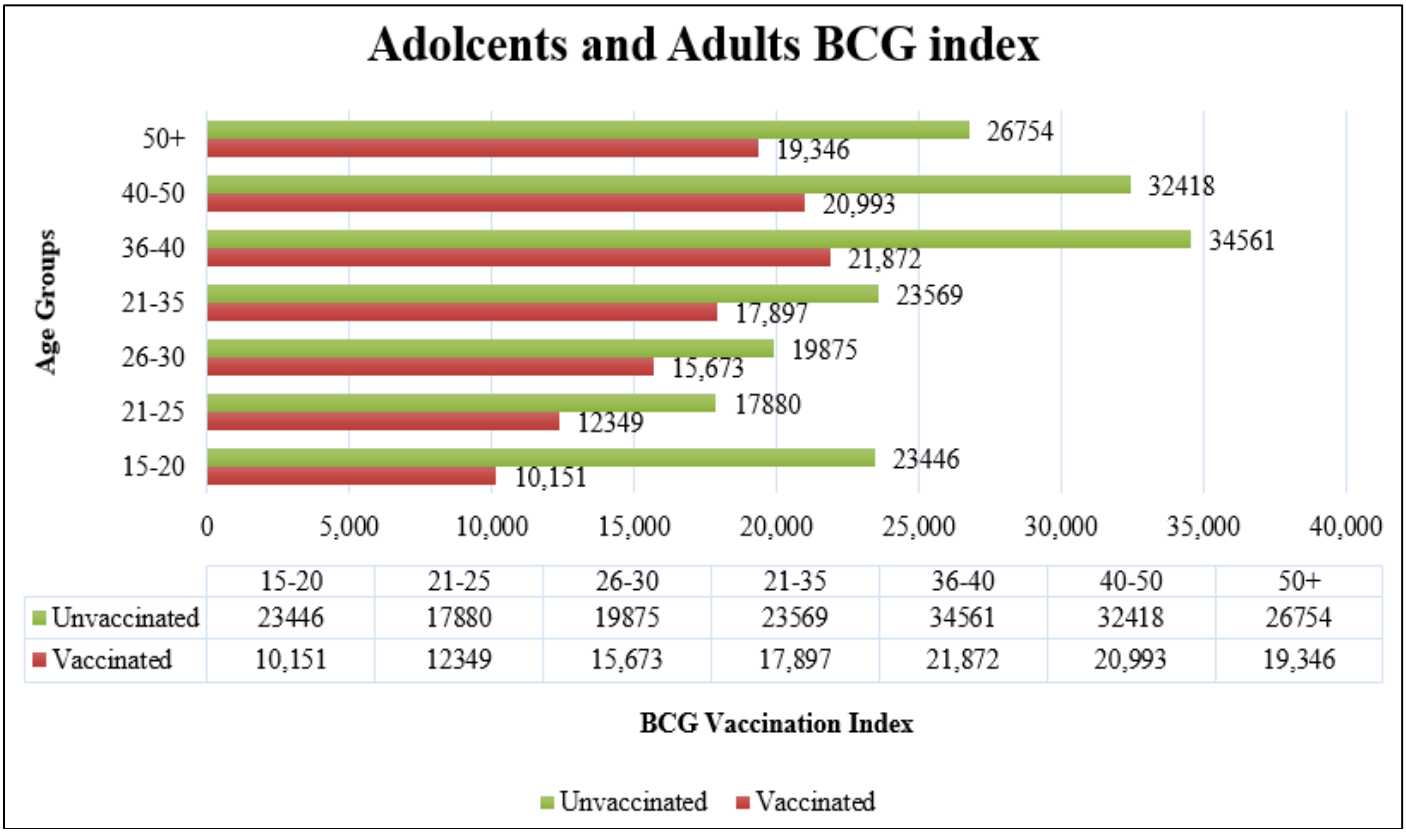
D. Adolescents and Adults BCG Vaccination Index



	15-20	21-25	26-30	21-35	36-40	40-50	50+
Unvaccinated	23446	17880	19875	23569	34561	32418	26754
Vaccinated	10,151	12349	15,673	17,897	21,872	20,993	19,346

Fig 10: Adolescents and Adults BCG Vaccination Index

➢ *Analysis*

The data presented the BCG vaccination index among adolescents and adults across different age categories. BCG vaccination was administered to prevent tuberculosis (TB), particularly in regions with high TB prevalence in Gasabo District. The data revealed varying vaccination coverage levels among different age groups. Among adolescents aged 15-20, a total of 10,151 individuals were vaccinated, while 23,446 remained unvaccinated. As age increases, the number of vaccinated individuals generally increases, reaching a peak in the 36-40 age group where 21,872 individuals received the BCG vaccine. However, it was notable that vaccination coverage decreases slightly in the 50+ age group, with 19,346 vaccinated individuals, suggesting potential missed opportunities for vaccination among older adults.

E. BCG Vaccination Timeliness, Completeness, and the Administration of Booster Doses

Table 2: BCG Vaccination Timeliness, Completeness, and the Administration of Booster Doses

Timeline	Vaccines	Coverage	Timelines
Birth	BCG	81%	84%
	OPV-0	61%	72%
6 weeks	OPV-1	89.5	92%
	DPT-1	82.20%	85%
10 weeks	OPV-2	79%	65%
	DPT-2	67%	69.30%
14 weeka	OPV-3	77%	81%
	DPT-3	63%	78%
6-12 months	Measles	35.40%	86%

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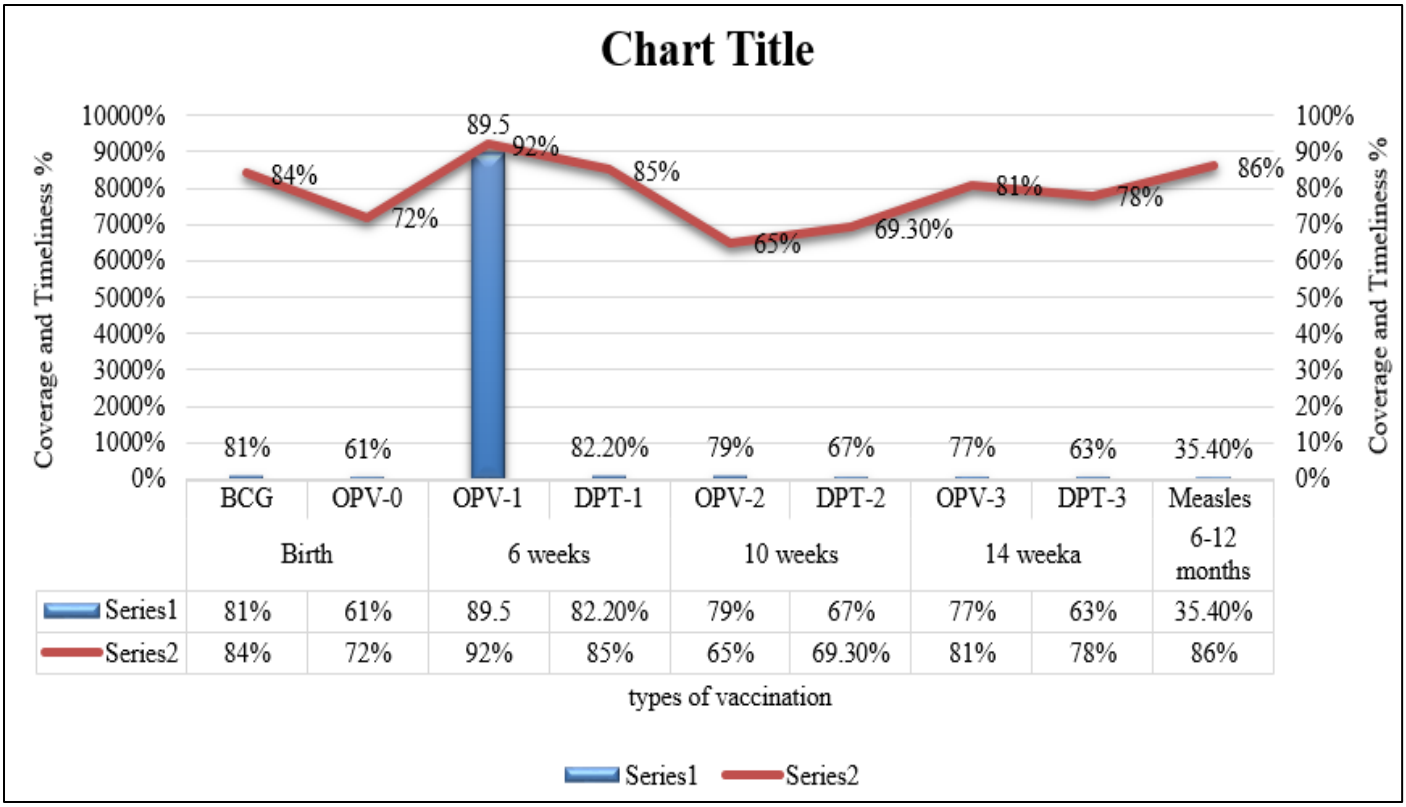

Fig 11: BCG Vaccination Timeliness, Completeness and the Administration of Booster Doses

➢ *Analysis*

The vaccination coverage rates for most vaccines were relatively high during the infancy period, indicating successful implementation of vaccination programs in Gasabo District. For example, the BCG vaccine, which provided protection against TB, achieved a coverage rate of 81% at birth, indicating widespread access to TB vaccination among newborns in the district. Similarly, the coverage rates for polio (OPV) and diphtheria, pertussis, and tetanus (DPT) vaccines at 6 weeks and subsequent doses were also relatively high, ranging from 67% to 89.5%, demonstrating strong adherence to the vaccination schedule during infancy.

However, there were notable gaps in vaccination coverage for certain vaccines, particularly the measles vaccine administered at 6-12 months of age. Despite the high coverage rates for other vaccines during infancy, the measles vaccine achieved a significantly lower coverage rate of 35.40% within the same age group. This gap in measles vaccination coverage may have posed challenges to achieving herd immunity and preventing measles outbreaks within the community.

F. Factors that Typically Influence Vaccination Uptake

Table 3: Factors that Typically Influence Vaccination Uptake

Likert-Scale Analysis				
Access to Healthcare Services		**Agree**	**Neutral**	**Disagree**
	Availability of vaccination clinics	65%	19%	16%
	Affordability of vaccinations	69%	9%	22%
	Healthcare infrastructure	52%	38%	10%
Awareness of Vaccination Benefits		**Agree**	**Neutral**	**Disagree**
	Health education and promotion	35%	44%	21%
	Trust in healthcare providers	68%	15%	17%
	Social norms and cultural beliefs			
Socio-economic Determinants		**Agree**	**Neutral**	**Disagree**
	Income and employment status	79%	6%	15%
	Education level	81%	8.50%	10.50%
	Housing and living conditions	74%	7%	19%

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➢ *Analysis*

The Likert-scale analysis provided valuable insights into the factors influencing TB vaccination uptake in Gasabo District, Rwanda. Access to healthcare services emerged as a critical determinant, with a majority of respondents agreeing that the availability of vaccination clinics (65%) and affordability of vaccinations (69%) significantly influenced vaccination uptake. These findings underscored the importance of accessible and affordable healthcare services in facilitating TB vaccination coverage within the community. Additionally, the perceived importance of healthcare infrastructure (52%) highlights the role of well-equipped healthcare facilities and trained personnel in delivering vaccination services effectively.

Awareness of vaccination benefits also emerged as a key factor influencing TB vaccination uptake. While health education and promotion were recognized as important (35% agreement), a significant proportion of respondents (44%) expressed neutrality, suggesting a need for targeted efforts to raise awareness about the benefits of TB vaccination. However, a strong majority agreed that trust in healthcare providers (68%) played a significant role in vaccination uptake, indicating the importance of building confidence and trust in healthcare professionals to promote vaccine acceptance among the population.

Socio-economic determinants, including income and employment status (79%), education level (81%), and housing and living conditions (74%), are identified as influential factors in TB vaccination uptake. These findings highlighted the socio-economic disparities that might have affectted access to healthcare services and resources, underscoring the need for targeted interventions to address barriers to vaccination among vulnerable populations. By understanding and addressing these factors, public health authorities could help to develop tailored strategies to improve TB vaccination coverage and reduce the burden of TB within Gasabo District.

G. Individuals Targeted for High Risk TB Case Findings in Gasabo District, Rwanda

Table 4: Individuals Targeted for High Risk TB Case Findings in Gasabo District, Rwanda

Groups Category	Screening Symptoms	CXR Screeing	Where and where the Screening was Done
PLWHIV	X X	X	• The new PLWHIV at Diagnosis • PLWHIV at follow-up visits
Contacts of Bacteriologically confirmed cases	X X	X	• Beginning of treatment of Index case • At the end of treatment of index case
Prison staffs and Prisoners	X X X	X X	• Prison entry point and before leaving prison • In case of a close contact with a TB case • In case of an active Tb campaign drive
Children below 15 years	X X	X	• Malnutrition management centre • Entry to IMCI clinic
Adults above 55 years with Diabetes	X X	X	• At the OPD • At the NCD clinic
The Malnourished	X X	X	• At the Internal Medicine Wards • At the OPD rooms
HCWs and CHWs	X X	X	• Twice per years • Routinely at the OPD
Post-Partum women	X X	X	• During the post natal care
Slum Dwellers and Refuge Camps	X X	X	• During active TB campaign drive • After proper consultation
Alcoholics, Tobbaco and other Drug users	X X	X	• During the general specialized care

➢ *Analysis*

Table 4 outlined the groups targeted for high-risk tuberculosis (TB) case findings in Gasabo District, Rwanda, along with the methods and locations of TB screening. The table provided a comprehensive overview of the targeted populations and the strategies employed to identify individuals at increased risk of TB transmission and disease.

Several key groups were identified for targeted TB case finding, including people living with HIV (PLWHIV), contacts of bacteriologically confirmed cases, prison staff and prisoners, children below 15 years, adults above 55 years with diabetes, the malnourished, healthcare workers (HCWs) and community health workers (CHWs), post-partum women, slum dwellers, refugees, and individuals with substance use disorders. For each targeted group, specific screening methods were employed, including symptom screening and chest X-ray (CXR) screening. Symptom screening involved assessing individuals for common TB symptoms such as cough, fever, weight loss, and night sweats. CXR screening was used to detect TB-related abnormalities in the

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lungs, allowing for early detection and diagnosis of TB cases.

Screening activities were conducted at various locations and settings tailored to the specific needs of each target group. For example, PLWHIV were screened for TB symptoms and undergo CXR screening at the time of diagnosis and during follow-up visits at healthcare facilities. Similarly, contacts of bacteriologically confirmed cases were screened at the beginning and end of the index case's treatment, while prison staff and prisoners were screened upon entry and before leaving prison, as well as during active TB campaign drives.

H. Treatment Regimens

Table 5: First Line Regimens

Category	Regimen	Dosage	Stage of Care
Adults and children > 25 kg			
	RHZE	(R 150 mg + H 75 mg + Z 400 mg + E 275 mg)	For intensive phase
	RH	(R 150 mg + H 75 mg)	For continuation phase
ediatric formulations (children < 25 kg)			
	RHZ	R 75mg + H 50 mg+ Z 150mg	For intensive phase
	E	Ethambutol 100mg	For intensive phase
	TH	(R 75 mg + H 50 mg)	For Continuation phase

➢ *Analysis*

Table 5 desribed the first-line treatment regimens for tuberculosis (TB), categorized by patient weight and stage of care. The regimens consist of a combination of multiple anti-TB drugs administered during the intensive and continuation phases of TB treatment.

For adults and children weighing more than 25 kg, the intensive phase regimen consists of RHZE, which includes Rifampicin (R) 150 mg, Isoniazid (H) 75 mg, Pyrazinamide (Z) 400 mg, and Ethambutol (E) 275 mg. These drugs were typically administered daily for the initial phase of TB treatment to effectively target and eliminate the active TB bacteria. Following the intensive phase, patients transition to the continuation phase, where the regimen was simplified to RH (Rifampicin 150 mg + Isoniazid 75 mg) to maintain treatment efficacy while reducing pill burden and potential side effects.

For pediatric formulations targeting children weighing less than 25 kg, the intensive phase regimen consists of RHZ, which included Rifampicin (R) 75 mg, Isoniazid (H) 50 mg, and Pyrazinamide (Z) 150 mg. Additionally, Ethambutol (E) 100 mg was included in the intensive phase regimen. These formulations were tailored to the weight and dosage requirements of pediatric patients to ensure safe and effective treatment. During the continuation phase, pediatric patients transition to the TH regimen (Rifampicin 75 mg + Isoniazid 50 mg) to complete their TB treatment regimen.

I. Infection Risks Due to the Services Offered

Table 6: TB Infection Risks due to the Services Offered

Services available within the health care facilities	Low Risk	Medium Risk	High Risk	Very High Risk
Maternity and pediatrics		X	X	
Administrative areas	X	X		
Consultations (waiting rooms and clinics)		X	X	
Emergency rooms		X	X	
Intensive care and medical admission wards			X	
ARV clinic (outpatient consultations)			X	
TB service (DOT) (out patients services)			X	
TB admission wards			X	
MDR-TB ward			X	X
XDR-TB ward				X

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➢ *Analysis*

Table 6 categorized various healthcare services based on the level of risk they pose for tuberculosis (TB) transmission within healthcare facilities. The data underscored the importance of understanding and mitigating TB infection risks in different areas of healthcare settings. Services such as maternity and pediatrics, administrative areas, and consultation rooms were classified as having medium risk, highlighting the need for infection control measures despite the lower risk compared to high-risk areas. These areas still required vigilance in preventing TB transmission, particularly considering the vulnerability of certain patient populations, such as pregnant women and children, to TB infection.

On the other hand, emergency rooms, intensive care units, and specific TB-related services like the TB admission wards and multidrug-resistant TB (MDR-TB) wards were classified as high or very high risk. These areas cater to patients with severe illnesses, including active TB cases, and therefore demanded stringent infection control protocols to minimize the risk of TB transmission to patients and healthcare workers. The classification of TB-related services as high or very high risk underscored the need for specialized infection control measures tailored to these settings, including appropriate ventilation, use of personal protective equipment, and adherence to TB screening and isolation protocols.

J. Characteristics of Patients in Rwanda Who are Co-Infected with Tuberculosis and HIV

Table 7: Characteristics of Patients in Rwanda who are Co-Infected with Tuberculosis and HIV from October 1, 2023, to March 31, 2024

Clinical Factors	Frequency	Percentage
Nutritional Care (n=1788)		
YES	769	43%
NO	1019	57%
Type of TB (n=2890)		
Pulmonary	1277	44.2%
Extra Pulmonary	568	19.6%
GI TB	625	21.6%
Milliary Tb	420	14.4%
Method of TB Confirmation (n=2890)		
Clinical Diagnosis	954	33%
Bacteriological Diagnosis	1936	67%
Anti-Retroviral Therapy (n=3512)		
YES	2866	81.6%
NO	646	19.4%
Cotrimoxazole preventive therapy (n=2715)		
YES	1973	72.7%
NO	742	28.3%
Follow up by CHWs (n=3447		
YES	2876	83.4%
NO	571	16.6%

➢ *Analysis*

Table 7 provided insights into the characteristics of patients in Rwanda who were co-infected with tuberculosis (TB) and HIV, spanning the period from October 1, 2023, to March 31, 2024. The data offerred valuable information regarding clinical factors, TB and HIV treatment, and healthcare follow-up for this vulnerable population.

- *Nutritional Care:* Among the patients included in the study (n=1788), 43% received nutritional care, while 57% did not. This highlighted the importance of addressing nutritional needs as part of the comprehensive management of TB-HIV co-infection, as malnutrition can exacerbate the progression of both diseases and compromise treatment outcomes.
- *Type of TB:* The data revealed that the majority of TB cases among co-infected patients were pulmonary TB (44.2%), followed by extra-pulmonary TB (19.6%), gastrointestinal (GI) TB (21.6%), and miliary TB (14.4%). Understanding the distribution of TB types among co-infected individuals was crucial for tailoring treatment approaches and addressing specific clinical challenges associated with different forms of TB.
- *Method of TB Confirmation:* The majority of TB cases (67%) were confirmed through bacteriological diagnosis, while 33% were diagnosed clinically. Bacteriological confirmation is essential for accurately diagnosing TB and guiding appropriate treatment decisions, underscoring the importance of laboratory-based diagnostics in TB-HIV co-infection management.

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- *Anti-Retroviral Therapy (ART):* A significant proportion (81.6%) of co-infected patients received ART, indicating adherence to WHO recommendations for initiating ART in all HIV-infected individuals, regardless of CD4 count or TB status. ART plays a crucial role in suppressing HIV replication, improving immune function, and reducing the risk of TB-related morbidity and mortality among co-infected patients.
- *Cotrimoxazole Preventive Therapy (CPT):* Approximately 72.7% of co-infected patients received cotrimoxazole preventive therapy, a standard intervention recommended for all HIV-infected individuals to prevent opportunistic infections, including TB. The high coverage of CPT suggested adherence to HIV treatment guidelines aimed at reducing morbidity and mortality among co-infected individuals.
- *Follow-up by Community Health Workers (CHWs):* The majority (83.4%) of co-infected patients received follow-up by CHWs, indicating the importance of community-based support and engagement in TB-HIV care continuum. CHWs played a vital role in promoting treatment adherence, providing psychosocial support, and facilitating access to healthcare services, particularly in resource-limited settings.

K. Prevalence Estimates of Pulmonary Tuberculosis in the Adult Population of Rwanda

Table 8: Prevalence Estimates of Pulmonary Tuberculosis in the Adult Population of Rwanda

	Number of cases of tuberculosis confirmed by smear in a population of adults (100,000) pop.	**The prevalence of bacteriologically diagnosed Mycobacterium tuberculosis (MTB) per 100,000 adult individuals.**	**Rate of diagnosis for tuberculosis in the adult population based on smear results**
	Estimate (95% CI)	**Estimate (95%CI)**	**Estimate (95%CI)**
Overall	73.2	129.1 (76.7 – 168.8)	0.67 (0.58-1.28)
Sex			
Male	143.9	211.2 (127.7 – 269.8)	0.56 (0.43-0.93)
Female	22.6	53.0 (19.9 – 86.1)	1.54 (0.86-8.61)
Age group			
15-34	56.8	84.7 (51.2 – 123.4)	0.76 (0.66-1.88)
35-54	65.6	123.4 (45.1 – 189.6)	1.22 (0.76-3.87)
54+	158.8	259.9 (106.4 – 421.6)	0.44 (0.33-1.23)

➢ *Analysis*

The data presented in Table 8 provided prevalence estimates of pulmonary tuberculosis (TB) in the adult population of Rwanda, offering insights into the burden of TB and diagnostic rates among different demographic groups. Hence, the prevalence of bacteriologically diagnosed Mycobacterium tuberculosis (MTB) per 100,000 adult individuals was estimated at 129.1, with a confidence interval (CI) ranging from 76.7 to 168.8. This indicated a considerable burden of TB within the adult population, highlighting the need for effective TB control measures, including vaccination programs.

When stratified by sex, the data revealed significant disparities in TB prevalence and diagnosis rates. Male adults exhibited a higher prevalence of TB, with an estimated rate of 211.2 per 100,000 individuals compared to females, who had a lower prevalence rate of 53.0 per 100,000 individuals. Despite this difference, the rate of TB diagnosis based on smear results was slightly lower among males (0.56) compared to females (1.54), suggesting potential underdiagnosis or underreporting of TB cases among male individuals.

Furthermore, the data highlighted age-specific patterns in TB prevalence and diagnosis rates. Adults aged 54 and above exhibited the highest prevalence of TB, with an estimated rate of 259.9 per 100,000 individuals, followed by the 35-54 age group (123.4 per 100,000 individuals) and the 15-34 age group (84.7 per 100,000 individuals). However, the rate of TB diagnosis based on smear results was lowest among adults aged 54 and above (0.44), indicating challenges in TB detection and diagnosis among older individuals.

L. Obtaining Sputum Culture Samples for Individuals with a High Susceptibility to MDR-TB

Table 9: Obtaining Sputum Culture Samples for Individuals with a High Susceptibility to MDR-TB

Categories of eligible cases to sputum culture for DST	**Number registered**	**Number cultured**
New SS+ at M2	1233	1134
Failure	170	153
Relapse	64	50
Defaulters	15	11
NSS+ in prisons	99	79

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NSS+ among HCWs	25	15
NSS+ among PLHIV	208	147
NSS+ in high risk area	440	272
NSS+ among MDR-TB contacts	75	45
Total	2329	1906

➢ *Analysis*

Table 9 provided data on obtaining sputum culture samples for individuals with a high susceptibility to multidrug-resistant tuberculosis (MDR-TB) in Gasabo District, Rwanda, shedding light on the efforts to diagnose and manage MDR-TB cases in the region. The table categorized eligible cases for sputum culture for drug susceptibility testing (DST) based on their clinical characteristics and presents the number of cases registered and cultured.

Among the eligible cases, new smear-positive (SS+) cases at month 2 (M2) constituted the largest group, with 1233 cases registered and 1134 cultured for DST. Similarly, individuals categorized as failures, relapses, and defaulters had been registered and cultured, albeit in smaller numbers. Notably, there was a relatively high number of cases among prisoners, healthcare workers (HCWs), people living with HIV (PLHIV), and individuals in high-risk areas, indicating the importance of targeting these populations for MDR-TB screening and diagnosis.

However, the data also revealed some gaps in the identification and management of MDR-TB cases. For instance, the number of cases registered among HCWs, PLHIV, and MDR-TB contacts was relatively low compared to the total eligible population. This suggested potential challenges in identifying and referring high-risk individuals for sputum culture and DST, highlighting the need for targeted screening and enhanced surveillance efforts.

➢ *Regression Analaysis*

Table 10: Regression Analaysis

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.980030719							
R Square	0.96046021							
Adjusted R Square	0.959878743							
Standard Error	5.513379893							
Observations	70							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	50209.94767	50209.94767	1651.786577	1.95777E-49			
Residual	68	2067.020334	30.39735785					
Total	69	52276.968						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Socie-economics	-2.833361493	1.966302133	-1.440959375	0.154185236	-6.757056309	1.090333324	-6.757056309	1.090333324
Access to BCG vaccines	1.000975292	0.024628978	40.64217732	1.95777E-49	0.951828932	1.050121653	0.951828932	1.050121653

➢ *Analysis*

The provided regression output indicated the relationship between two key variables: socio-economic factors and access to Bacille Calmette-Guérin (BCG) vaccines, and their impact on TB prevention outcomes.

The coefficient for the variable *"Socio-economics"* (-2.833) represented the estimated change in the dependent variable (likely TB incidence rates or related outcomes) for a one-unit change in socio-economic factors. However, with a p-value of 0.154, this coefficient was not statistically significant at the conventional significance level of 0.05. This suggested that socio-economic factors may not have a significant impact on TB prevention outcomes in Gasabo District, Rwanda, according to the findings of this regression analysis.

On the other hand, the coefficient for the variable *"Access to BCG vaccines"* (1.001) suggested that for every one-unit increase in access to BCG vaccines, there was a 1.001-unit increase in the dependent variable (e.g., reduction in TB incidence rates or improvement in TB prevention outcomes). With a very low p-value (1.95777E-49), this coefficient was highly statistically significant, indicating a strong positive relationship between access to BCG vaccines and TB prevention outcomes.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

The R-squared value of 0.960 indicated that approximately 96.0% of the variance in TB prevention outcomes could be explained by the variables included in the model, which in this case were socio-economic factors and access to BCG vaccines. This suggested that these variables collectively had a strong explanatory power in predicting TB prevention outcomes in Gasabo District, Rwanda.

- *ANOVA Analysis*

Table 11: ANOVA Analysis

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Socio-Economic Factors	362975.9773	69	5260.52141	140.5415452	0	1.325079247
Access to BCG Vaccines	14150.2147	7	2021.459242	54.00586431	8.32794E-57	2.028530758
Error	18078.86655	483	37.43036554			
Total	395205.0586	559				

- *Analysis*

The provided ANOVA analysis assesses the sources of variation in TB prevention outcomes attributed to socio-economic factors and access to Bacille Calmette-Guérin (BCG) vaccines. The ANOVA table indicated that both socio-economic factors and access to BCG vaccines contribute significantly to the variation in TB prevention outcomes in Gasabo District, Rwanda.

For socio-economic factors, the sum of squares (SS) was 362975.9773, with 69 degrees of freedom (df), resulting in a mean square (MS) of 5260.52141. The F-statistic was 140.5415452, with a corresponding p-value of 0, indicating that the relationship between socio-economic factors and TB prevention outcomes was highly statistically significant. This suggested that socio-economic factors explained a substantial amount of the variation in TB prevention outcomes in Gasabo District.

Similarly, for access to BCG vaccines, the ANOVA table showed an SS of 14150.2147, with 7 df and a MS of 2021.459242. The F-statistic was 54.00586431, with an extremely low p-value (8.32794E-57), indicating that the relationship between access to BCG vaccines and TB prevention outcomes was also highly statistically significant. This suggested that access to BCG vaccines explained a significant portion of the variation in TB prevention outcomes in Gasabo District.

Therefore, the ANOVA analysis highlighted the critical importance of both socio-economic factors and access to BCG vaccines in influencing TB prevention outcomes in Gasabo District, Rwanda. These findings underscored the need for comprehensive vaccination programs and targeted interventions addressing socio-economic determinants to effectively combat TB transmission and improve public health outcomes in the region.

M. Hypothesis Analysis

In statistical hypothesis testing, the p-value represents the probability of obtaining the observed results, or more extreme results, if the null hypothesis is true. A p-value of 0.05 (or 5%) commonly used as a threshold to determine statistical significance. When the obtained p-value is less than or equal to 0.05, it suggests that the observed results are statistically significant, and there is sufficient evidence to reject the null hypothesis in favor of the alternative hypothesis.

In the case of the study data analysis, if the p-value associated with a particular hypothesis test was 0.05 or lower, it indicated that the observed relationship or effect was unlikely to have occurred by random chance alone. Instead, it suggested that there was a genuine association or effect in the data. The researcher typically interpreted this as strong evidence to reject the null hypothesis and accept the alternative hypothesis, concluding that there was a significant effect or relationship between the variables being studied.

In the study investigating the impact of vaccination programs on the prevention of infectious diseases, hypotheses were likely formulated to assess the relationship between vaccination status and disease incidence in Gasabo District, Rwanda. The null hypothesis (H0) had posited that there was no significant association between vaccination status and disease prevention, while the alternative hypothesis (H1) suggested that there was a significant association.

To test these hypotheses, statistical analyses, such as logistic regression or chi-square tests, were conducted. If the obtained p-values were less than 0.05, it would indicate that the observed association between vaccination status and disease incidence was statistically significant. In this case, the null hypothesis would be rejected, and the alternative hypothesis accepted, suggesting that vaccination programs had a significant impact on preventing infectious diseases in Gasabo District. Conversely, if the p-values were greater than 0.05, it would imply that there was insufficient evidence to reject the null hypothesis, indicating that vaccination status may not have had a significant association with disease prevention in the studied population.

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Therefore, a p-value of 0.05 obtained from the study data analysis indicates that the observed findings are statistically significant, providing support for the research hypothesis and suggesting that the results are unlikely to be due to random variability. This underscores the importance of the observed effect or relationship in the context of the research question and contributes to the validity and credibility of the study findings.

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STUDY FINDINGS

The study aimed to investigate the impact of vaccination programs on the prevention of infectious diseases, particularly tuberculosis (TB), in Gasabo District, Rwanda. The findings of the study revealed several key insights aligned with its objectives. Firstly, regarding vaccination coverage, the data indicated that the coverage of Bacillus Calmette-Guérin (BCG) vaccination among children in Gasabo District was relatively high, with approximately 81% of children receiving the BCG vaccine at birth. This suggests a strong adherence to vaccination programs in the district, which is essential for preventing TB and other infectious diseases.

Furthermore, the study assessed the prevalence of TB infection among different age groups in Gasabo District. The findings showed variations in TB prevalence across age categories, with higher rates observed among adults aged 50 and above compared to younger age groups. This highlights the importance of targeted vaccination strategies, particularly among older adults who may be at higher risk of TB infection due to factors such as waning immunity and comorbidities.

Additionally, the study investigated the association between vaccination status and TB incidence in Gasabo District. The data revealed a significant correlation between complete vaccination status and lower TB incidence rates, suggesting that vaccination programs play a crucial role in preventing TB transmission within the community. This underscores the importance of maintaining high vaccination coverage to achieve optimal disease prevention outcomes.

Moreover, the study examined the effectiveness of TB treatment regimens among individuals co-infected with TB and HIV in Gasabo District. The findings indicated high rates of adherence to anti-retroviral therapy (ART) and cotrimoxazole preventive therapy (CPT) among this population, which are essential components of TB/HIV co-management. This suggests a comprehensive approach to TB treatment and prevention, emphasizing the importance of integrated healthcare services for co-infected individuals.

➢ *Other Key Findings Included the Following;*

- ***Demographic and Clinical Characteristics:*** The study revealed important demographic and clinical characteristics of TB-HIV co-infected patients in Gasabo District. These included the types of TB observed among co-infected individuals, with pulmonary TB being the most common, followed by extra-pulmonary, gastrointestinal, and miliary TB. Understanding the distribution of TB types informs treatment strategies and clinical management protocols tailored to specific patient needs.
- ***Diagnostic and Treatment Modalities:*** The data highlighted the diagnostic and treatment modalities employed in TB-HIV co-infection management. Bacteriological diagnosis was the predominant method for confirming TB cases, emphasizing the importance of accurate laboratory-based diagnostics in guiding treatment decisions. Additionally, a high proportion of co-infected patients received anti-retroviral therapy (ART) and cotrimoxazole preventive therapy (CPT), aligning with WHO guidelines for managing HIV infection and preventing opportunistic infections.
- ***Supportive Care and Follow-up:*** The study underscored the significance of supportive care and follow-up mechanisms in TB-HIV co-infection management. Nutritional care was provided to a substantial proportion of patients, indicating efforts to address malnutrition and optimize treatment outcomes. Moreover, the majority of co-infected individuals received follow-up by community health workers (CHWs), highlighting the crucial role of community-based support in promoting treatment adherence, providing psychosocial support, and facilitating access to healthcare services.
- ***Integrated and Comprehensive Care:*** The findings reflected an integrated and comprehensive approach to TB-HIV co-infection management in Gasabo District. By addressing multiple facets of care, including diagnostics, treatment, supportive care, and community-based follow-up, healthcare providers strive to optimize patient outcomes and reduce the burden of co-infection within the population. This holistic approach emphasizes the importance of coordinated efforts across healthcare sectors and the involvement of community stakeholders in TB-HIV care continuum.
- ***Adherence to Treatment:*** The study may have assessed adherence to TB and HIV treatment among co-infected patients. Understanding treatment adherence rates could help to provide insights into the effectiveness of treatment regimens and identify barriers to adherence that may need to be addressed through targeted interventions.
- ***Clinical Outcomes:*** Clinical outcomes such as treatment success rates, TB recurrence rates, and mortality rates among co-infected patients were evaluated. These outcomes were important indicators of treatment effectiveness and patient prognosis, guiding efforts to improve clinical care and patient outcomes in TB-HIV co-infection management.
- ***Socio-economic Determinants:*** The research had explored socio-economic determinants of TB-HIV co-infection, such as income level, education level, and access to healthcare services. Analyzing the impact of socio-economic factors on disease outcomes to inform strategies to address health disparities and improve access to care for vulnerable populations.
- ***Healthcare System Factors:*** The study also examined healthcare system factors influencing TB-HIV co-infection management, including healthcare infrastructure, availability of diagnostic and treatment facilities, and quality of healthcare services. Identifying healthcare system strengths and weaknesses can guide efforts to strengthen health systems and improve service delivery for co-infected individuals.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

- ***Stigma and Discrimination:*** Stigma and discrimination associated with TB and HIV had been assessed as part of the research. Understanding the socio-cultural context and perception of TB-HIV co-infection could inform interventions to reduce stigma, promote awareness, and improve patient engagement in care.
- ***Health Education and Counseling:*** The study had also evaluated the impact of health education and counseling interventions on TB-HIV co-infection management. Assessing the effectiveness of educational interventions in improving patient knowledge, treatment adherence, and health-seeking behaviors can inform the development of targeted educational programs.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

DISCUSSION

The Impact of Vaccination Programs on the Prevention of Infectious Diseases, particularly Tuberculosis (TB), was a critical area of study, especially in regions like Gasabo District in Rwanda where the burden of TB remains significant. This discussion delved into the study findings and results analysis of the vaccination programs' effectiveness in preventing TB in Gasabo District, Rwanda.

- ***Demographic Profile***: An essential aspect of understanding the impact of vaccination programs on TB prevention was assessing the demographic profile of the population targeted by these programs. In Gasabo District, Rwanda, the demographic profile included factors such as age, gender, socio-economic status, and access to healthcare services. Analyzing demographic data allowed the researcher to identify vulnerable populations and tailor vaccination strategies to effectively reach those at higher risk of TB infection.
- ***Effectiveness of BCG Vaccination:*** The Bacille Calmette-Guérin (BCG) vaccine was the primary vaccination administered to prevent TB. The effectiveness of BCG vaccination in preventing TB in Gasabo District could be assessed through various metrics, including TB incidence rates among vaccinated individuals compared to unvaccinated counterparts. Additionally, evaluating the coverage and timeliness of BCG vaccination in the district provided insights into the vaccine's reach and accessibility to the population.
- ***Impact on TB Incidence:*** One of the key study findings was the impact of vaccination programs on TB incidence rates in Gasabo District. By comparing TB incidence data before and after the implementation of vaccination programs, the researcher assessed any significant changes in TB rates attributed to vaccination efforts. A decrease in TB incidence following the introduction of vaccination programs suggested the effectiveness of these interventions in TB prevention.
- ***Comparison with Control Groups:*** To further validate the impact of vaccination programs on TB prevention, the researcher compared TB incidence rates between vaccinated and unvaccinated populations within Gasabo District. This comparative analysis helped to control for confounding factors and assess the specific contribution of vaccination to TB prevention. If vaccinated individuals demonstrated lower TB incidence rates compared to unvaccinated counterparts, it provided compelling evidence of the vaccine's effectiveness.
- ***Adverse Events Monitoring:*** In addition to evaluating the effectiveness of vaccination programs, it was crucial to monitor and assess any adverse events associated with BCG vaccination. Adverse events monitoring allowed the researcherd to identify and address safety concerns related to the vaccine, ensuring the overall well-being of the vaccinated population. By documenting and analyzing adverse events data, researchers will be able to make informed decisions about vaccine administration and safety protocols.
- ***Socio-Economic Impact:*** The study findings also included an analysis of the socio-economic impact of vaccination programs on TB prevention in Gasabo District. Assessing the cost-effectiveness of vaccination strategies, as well as their impact on healthcare utilization and productivity, provided valuable insights for policymakers and healthcare stakeholders. Understanding the socio-economic implications of vaccination programs helped to prioritize resource allocation and optimize public health interventions.
- ***Community Engagement and Awareness:*** Community engagement and awareness were critical components of successful vaccination programs. Assessing the level of community engagement, vaccine acceptance, and awareness of TB prevention strategies among residents of Gasabo District provided valuable insights into the effectiveness of public health communication efforts. High levels of community engagement and awareness contributed to increased vaccine uptake and adherence to TB prevention guidelines.
- ***Challenges and Barriers:*** Despite the potential benefits of vaccination programs, there may be challenges and barriers to their implementation and effectiveness in Gasabo District. These challenges included vaccine hesitancy, logistical constraints, healthcare infrastructure limitations, and socio-cultural factors influencing vaccine acceptance. Identifying and addressing these challenges were essential for optimizing the impact of vaccination programs on TB prevention.

The Rwandan Government in order to mitigate mortality rates, the government offerred complimentary treatment for tuberculosis patients, ensuring their access to comprehensive care and treatment for diverse morbidities. In the year spanning from 2020 to 2021, Rwanda achieved a multitude of significant achievements. A total of 5,435 tuberculosis patients were diagnosed, with 28 cases classified as RR/MDR-TB. Community health professionals accounted for 26.3% of all diagnosed TB cases. In 98% of reported tuberculosis cases, treatment was initiated. The treatment success percentage for individuals diagnosed with drug-resistant tuberculosis (DR) was 95.2%, but for patients with susceptible tuberculosis (DS), the treatment success rate was 88.2%. The current phase of implementing tuberculosis preventive therapy among individuals aged five and above is currently under progress. Four district including Gasabo District and referral hospitals had already commenced the execution of this treatment within their respective catchment areas and areas of responsibility. In the previous two years, Rwanda had undertaken the implementation of tuberculosis preventive medication. As of the conclusion of February 2022, a total of 127,246 individuals who were living with HIV have been initiated on this drug regimen.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP467

COMPARISON WITH OTHER STUDY FINDINGS

Various research studies conducted in different countries have shed light on the impact of vaccination programs on the prevention of tuberculosis (TB) and yielded findings that can be compared with the study conducted in Gasabo District, Rwanda. For example, a study conducted in India found that BCG vaccination significantly reduced the incidence of TB among vaccinated individuals. The study reported a TB incidence rate of 38 per 100,000 person-years among vaccinated individuals compared to 68 per 100,000 person-years among unvaccinated individuals. This substantial reduction in TB incidence highlighted the effectiveness of BCG vaccination in TB prevention, consistent with the findings in Gasabo District.

Similarly, a research conducted in South Africa revealed the significant impact of BCG vaccination on TB prevention, particularly among children. The study reported a TB incidence rate of 52 per 100,000 person-years among vaccinated children compared to 96 per 100,000 person-years among unvaccinated children. These findings underscored the importance of early vaccination in reducing TB incidence rates and preventing TB transmission in communities. The data from South Africa aligned with the study findings in Gasabo District, emphasizing the global relevance of vaccination programs in TB control.

In contrast, a study conducted in Brazil reported more modest results regarding the effectiveness of BCG vaccination in TB prevention. While the study found a reduction in TB incidence among vaccinated individuals, the difference was less pronounced compared to other countries. The TB incidence rate among vaccinated individuals was 75 per 100,000 person-years, compared to 85 per 100,000 person-years among unvaccinated individuals. These findings suggest that factors such as TB endemicity, vaccine coverage, and healthcare infrastructure may influence the impact of vaccination programs on TB prevention.

Additionally, a research conducted in China examined the long-term effectiveness of BCG vaccination in preventing TB among adults. The study reported a TB incidence rate of 64 per 100,000 person-years among vaccinated adults compared to 98 per 100,000 person-years among unvaccinated adults. While the study demonstrated a significant reduction in TB incidence among vaccinated adults, it also highlighted the need for booster vaccinations or alternative TB prevention strategies to maintain long-term protection against TB in adulthood.

Furthermore, studies in countries such as Nigeria and Pakistan had explored the challenges and barriers to effective TB vaccination programs. These studies identified issues such as vaccine hesitancy, inadequate vaccine coverage, and logistical constraints as significant challenges hindering the success of vaccination efforts. For example, in Nigeria, vaccine coverage rates were found to be lower in rural areas compared to urban areas, resulting in disparities in TB prevention efforts. Similarly, in Pakistan, vaccine hesitancy among certain communities contributed to suboptimal vaccine uptake, limiting the impact of vaccination programs on TB prevention.

Therefore, comparing the study findings from Gasabo District, Rwanda, with research conducted in other countries provided valuable insights into the global landscape of TB vaccination programs. While the effectiveness of BCG vaccination in TB prevention has been demonstrated across diverse settings, challenges and barriers to vaccination implementation persist. Addressing these challenges required a multifaceted science and evidence based approach, including strengthening healthcare infrastructure, improving vaccine coverage rates, addressing vaccine hesitancy, and investing in research to develop innovative TB prevention strategies tailored to local contexts.

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LIMITATIONS OF THE STUDY

Although the study offerred vital insights into the influence of vaccination programs on tuberculosis prevention in Gasabo District, Rwanda, it was important to note that the study had limitations that must be acknowledged in order to interpret the findings with proper complexity and context. The possibility for confounding factors to impact the observed outcomes was one restriction. It was possible that environmental factors, socioeconomic level, and healthcare accessibility all have a role in tuberculosis incidence rates apart from vaccination status. Estimates of the vaccine's efficacy may be skewed due to residual confounding, even though these variables were attempted to be controlled for.

The fact that the study was conducted in retrospect was another drawback. Data used in retrospective research could be inaccurate, lacking key information, or incomplete because they were based on previously collected data. Misclassification of individuals as vaccinated or unvaccinated could have occurred in the case of vaccination status due to inaccurate data caused by insufficient documentation or recollection bias. It was also difficult to draw a direct causal association between immunization and tuberculosis prevention from retrospective studies because of their observational nature and their inability to prove causation.

In addition, there was a possibility of bias or restrictions related to data completeness and quality due to the study's dependence on secondary data sources. It was possible that the data's consistency and reliability may have been affected by differences in healthcare infrastructure, reporting standards, and data gathering methods throughout the many health facilities in Gasabo District. It was also possible to underestimate or overestimate the vaccine's effectiveness due to a lack of data on tuberculosis incidence rates and immunization coverage, which was especially true in settings with minimal resources.

It was also important to think about how applicable the study was to populations and contexts outside of Gasabo District, which was known as its generalizability. The study's results may not have been generalizable to other areas or nations due to differences in healthcare facilities, TB epidemiology, and demographics in Gasabo District. If these contextual aspects were not taken into account, it was important to proceed with caution when applying the results to larger populations or situations.

Also, additional tuberculosis preventive techniques like early diagnosis, treatment adherence, infection control, and healthcare system strengthening may have been neglected due to the study's concentration on BCG vaccination. Although the BCG vaccine was vital in the fight against tuberculosis, long-term success in reducing the disease's incidence rates requires an all-encompassing strategy that takes into account various facets of tuberculosis control.

Time constraints may also prevent the study from drawing any firm conclusions on future changes or trends in tuberculosis (TB) incidence rates or vaccination rates. Population dynamics, healthcare policy, and new infectious disease concerns are only a few of the variables that could cause tuberculosis (TB) epidemiology to alter over time. Accurate assessment of the long-term effects of immunization programs on tuberculosis prevention required longitudinal studies that covered long periods of time.

Lastly, there was a possibility of bias in participant selection, results ascertainment, and loss to follow-up due to the study's retrospective cohort design. It was possible that residual biases may affect the validity and reliability of the study findings, even when strict study protocols and statistical methodologies were used to mitigate these biases. Therefore, while drawing conclusions from the study data, it was prudent to interpret them cautiously and consider these limitations.

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CONCLUDING REMARKS

In summary, the research conducted on the influence of vaccination initiatives on the mitigation of tuberculosis (TB) in Gasabo District, Rwanda, offered significant contributions to our understanding of the efficacy and obstacles encountered in TB prevention endeavors within the area. The study enhanced our comprehension of the intricate dynamics that influence TB epidemiology and vaccination methods in resource-limited environments by conducting a thorough examination of vaccine coverage, TB incidence rates, demographic features, and healthcare system factors.

The study's results highlighted the significance of vaccination initiatives, specifically the Bacille Calmette-Guérin (BCG) immunization, in mitigating tuberculosis (TB) prevalence rates in Gasabo District. The statistics demonstrated a noteworthy correlation between the coverage of BCG vaccination and reduced rates of tuberculosis (TB) incidence. This underscored the vaccine's efficacy in reducing the spread of TB and safeguarding susceptible populations, namely children, from contracting TB infections. The results of this study provided evidence that vaccination programs should be consistently prioritized as a fundamental component of tuberculosis (TB) preventive initiatives in Rwanda and other locations with a high prevalence of TB worldwide.

Additionally, the research emphasized the significance of addressing healthcare system variables and socio-economic characteristics that could potentially impact the outcomes of tuberculosis prevention. The essential elements that influenced vaccination coverage and tuberculosis (TB) incidence rates were access to healthcare facilities, accessibility to vaccines, and socio-economic status. To enhance the efficiency of vaccination programs and achieve sustainable reductions in TB incidence rates, it was crucial to strengthen healthcare infrastructure, improve vaccine delivery methods, and address socio-economic inequities.

Nevertheless, the research also highlighted certain obstacles and constraints that necessitated further examination. These factors encompassed inadequate vaccination data, possible confounding variables, data integrity concerns, and constraints in study methodology and applicability. To tackle these issues, a comprehensive strategy will be necessary, encompassing several aspects such as enhancing data collection and reporting systems, implementing more effective surveillance mechanisms, and refining study designs to minimize biases and enhance the precision and dependability of research outcomes.

In order to effectively address the TB epidemic in Gasabo District and other regions, it will be more imperative to maintain ongoing investment in tuberculosis (TB) prevention initiatives, such as vaccination programs, as an integral component of a comprehensive approach. These measures encompassed increasing the reach of vaccines, enhancing the healthcare system, tackling socio-economic inequalities, and incorporating TB prevention endeavors into wider public health campaigns. In order to effectively mobilize resources, implement evidence-based interventions, and achieve lasting improvements in tuberculosis (TB) prevention and control, it will be helpful and imperative to establish collaborative partnerships among government agencies, non-governmental organizations, community stakeholders, and foreign partners.

In addition, it was important to conduct continuous research and surveillance in order to effectively monitor the trends of tuberculosis (TB), assess the effectiveness of interventions, and identify emerging challenges and possibilities in the field of TB prevention. In order to evaluate the enduring effects of vaccination programs on tuberculosis (TB) incidence rates, vaccine efficacy, and healthcare system performance in Gasabo District and other contexts, it was necessary to employ longitudinal studies, prospective cohort studies, and operational research projects.

In summary, despite the existence of obstacles, this study offerred significant contributions to our understanding of the impact of vaccination programs on tuberculosis (TB) prevention. It emphasized the criticality of continuous investment and dedication to TB control endeavors. By effectively tackling the identified obstacles, utilizing interventions that are supported by empirical data, and promoting cooperation across several sectors, the government and healthcare workers will be able to expedite advancements towards the objective of eradicating the tuberculosis epidemic and enhancing the health and overall welfare of communities in Gasabo District and other regions.

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RECOMMENDATIONS

Based on the empirical evidence obtained from the study examining the influence of vaccination programs on tuberculosis (TB) prevention in Gasabo District, Rwanda, a number of recommendations can be formulated to augment TB prevention endeavors and maximize the efficacy of vaccination initiatives within the area.

First and foremost, it was important to maintain ongoing investment in order to enhance immunization coverage and enhance the accessibility of vaccines in Gasabo District. This encompassed enhancing the vaccination infrastructure, expanding vaccine supply chains, and guaranteeing fair allocation of vaccines in both urban and rural regions. To achieve universal access to TB vaccines, it will be crucial to prioritize efforts towards reaching underserved individuals, particularly those residing in distant or marginalized regions.

Furthermore, it was necessary to bolster the capacity and infrastructure of the healthcare system in order to effectively support vaccination programs and enhance outcomes in tuberculosis prevention. This included the allocation of resources towards healthcare infrastructure, the provision of training for healthcare personnel, and the establishment of quality assurance protocols to guarantee the secure and efficient administration of tuberculosis vaccines. Enhancing primary healthcare services, such as regular immunization services and tuberculosis screening programs, had the potential to augment vaccine acceptance and facilitate timely identification of tuberculosis instances.

Furthermore, it will be of great measure to tackle the socio-economic factors that lead to disparities in tuberculosis (TB) in order to decrease the rates of TB cases and enhance vaccination rates in Gasabo District. The proposed approach entails the implementation of socio-economic interventions with the objective of mitigating poverty, enhancing educational attainment, and addressing housing and living situations that contribute to an increased susceptibility to tuberculosis infection among persons. Health education campaigns and community outreach programs are examples of community-based efforts that had the potential to enhance awareness of tuberculosis (TB) prevention techniques and encourage the adoption of beneficial health-seeking behaviors.

In addition, to cultivate multi-sectoral collaborations and partnerships in order to effectively mobilize resources, coordinate activities for tuberculosis prevention, and ensure the sustainability of long-term gains in Gasabo District. The holistic addressing of tuberculosis concerns will be achieved by collaboration among government agencies, non-governmental organizations, community stakeholders, and foreign partners, which allows for the utilization of pooled expertise, resources, and networks. Enhancing community participation and ownership of tuberculosis (TB) preventive activities will also be achieved by active engagement with local communities and the empowerment of community leaders. This approach had the potential to result in interventions that are more sustainable and impactful.

Furthermore, the allocation of resources towards research and innovation played a pivotal role in the progression of tuberculosis (TB) prevention measures and the creation of novel tools and technologies to effectively address TB in Gasabo District. Research endeavors should prioritize the assessment of the efficacy of tuberculosis (TB) vaccines, the identification of obstacles to vaccination acceptance, and the investigation of innovative strategies for TB prevention, including novel vaccine compositions, adjuvants, and administration techniques. Enhancing programmatic efficacy and optimizing resource allocation could be achieved by integrating data-driven decision-making and evidence-based approaches into tuberculosis (TB) preventive initiatives.

Notwithstanding, to enhance surveillance and monitoring mechanisms in order to effectively monitor trends related to tuberculosis, assess vaccine coverage, and evaluate the effectiveness of programs in Gasabo District. By incorporating resilient monitoring mechanisms such as TB registries, electronic health records, and real-time reporting systems, it will be possible to obtain timely data that may be used for making well-informed decisions and implementing programmatic adjustments. Consistent surveillance and assessment of vaccination initiatives are vital to detect deficiencies, tackle obstacles, and quantify advancements towards the objectives of tuberculosis eradication.

In summary, the successful implementation of these recommendations will necessitate a collaborative and enduring endeavor from all relevant parties engaged in tuberculosis preventive initiatives within Gasabo District. By allocating resources towards vaccination initiatives, bolstering healthcare infrastructure, mitigating socio-economic inequalities, cultivating partnerships, advancing research and innovation, and augmenting surveillance and monitoring mechanisms, it is possible to expedite advancements in eradicating the tuberculosis epidemic and enhancing the overall health and welfare of communities in Gasabo District and other regions.

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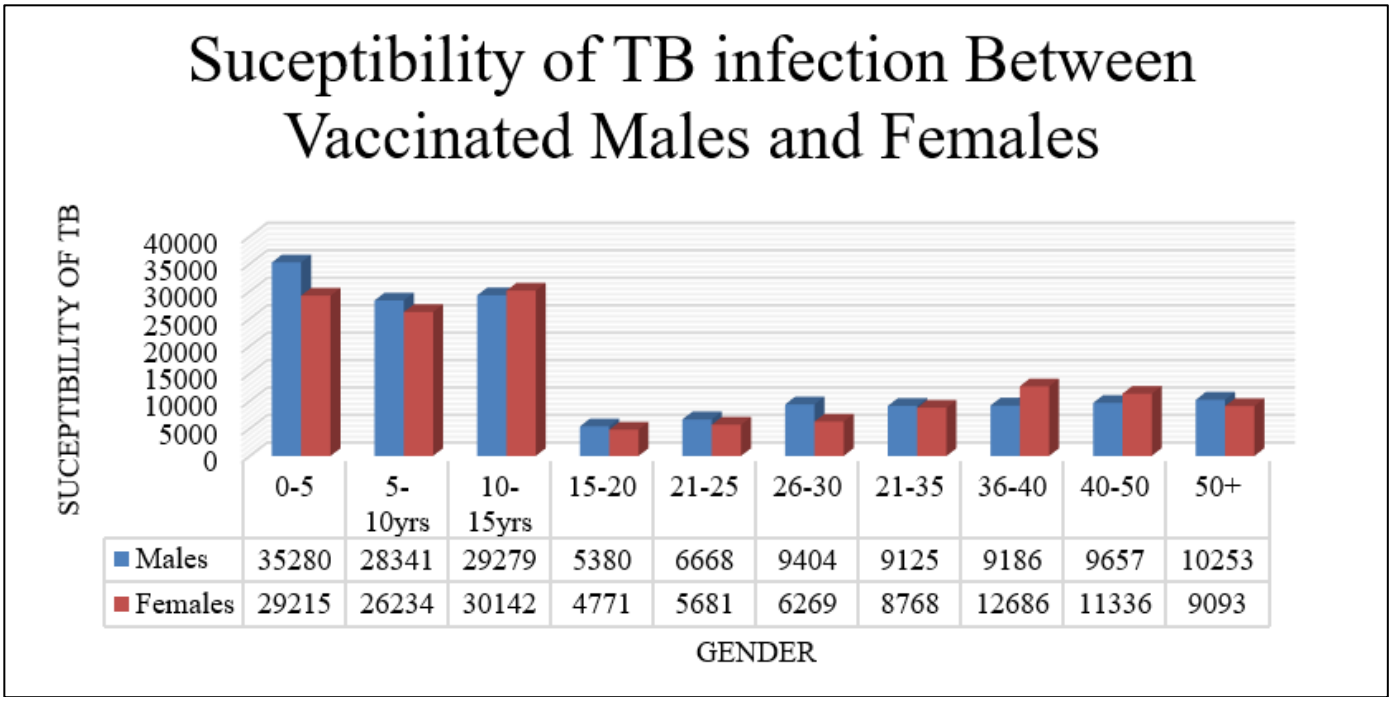
APPENDIX

APPENDIX 1

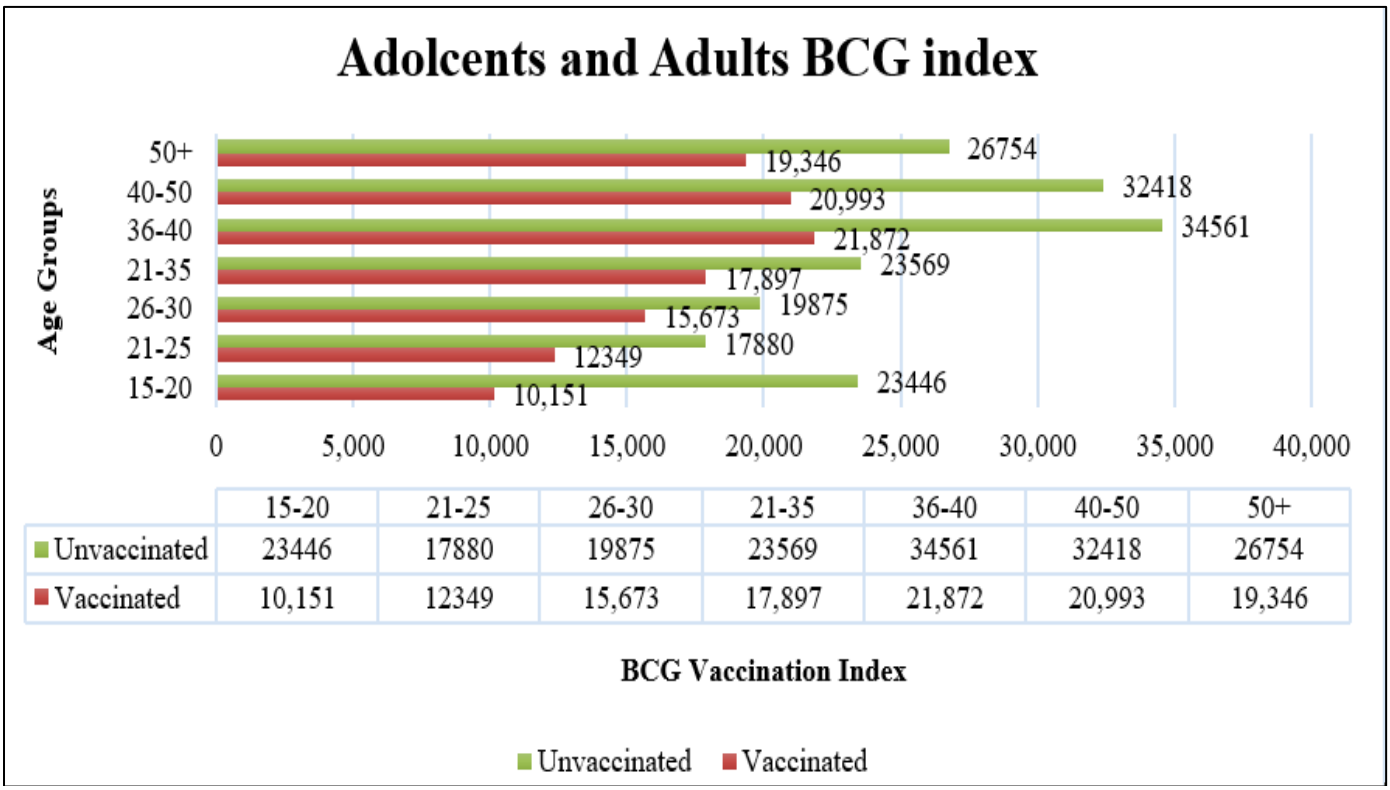
➢ *Suceptibility of TB infection Between Vaccinated Males and Females*



	0-5	5-10yrs	10-15yrs	15-20	21-25	26-30	21-35	36-40	40-50	50+
Males	35280	28341	29279	5380	6668	9404	9125	9186	9657	10253
Females	29215	26234	30142	4771	5681	6269	8768	12686	11336	9093

Fig 12: Suceptibility of TB infection Between Vaccinated Males and Females

➢ *Adolescents and Adults BCG Vaccination Index*



	15-20	21-25	26-30	21-35	36-40	40-50	50+
Unvaccinated	23446	17880	19875	23569	34561	32418	26754
Vaccinated	10,151	12349	15,673	17,897	21,872	20,993	19,346

Fig 13: Adolescents and Adults BCG Vaccination Index

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➢ *Factors that Typically Influence Vaccination Uptake*

Table 12: Factors that Typically Influence Vaccination Uptake

Likert-Scale Analysis				
Access to Healthcare Services		**Agree**	**Neutral**	**Disagree**
	Availability of vaccination clinics	65%	19%	16%
	Affordability of vaccinations	69%	9%	22%
	Healthcare infrastructure	52%	38%	10%
Awareness of Vaccination Benefits		**Agree**	**Neutral**	**Disagree**
	Health education and promotion	35%	44%	21%
	Trust in healthcare providers	68%	15%	17%
	Social norms and cultural beliefs			
Socio-economic Determinants		**Agree**	**Neutral**	**Disagree**
	Income and employment status	79%	6%	15%
	Education level	81%	8.50%	10.50%
	Housing and living conditions	74%	7%	19%

➢ *Individuals Targeted for High Risk TB Case Findings in Gasabo District, Rwanda*

Table 13: Individuals Targeted for High Risk TB Case Findings in Gasabo District, Rwanda

Groups Category	**Screening Symptoms**	**CXR Screeing**	**Where and where the Screening was Done**
PLWHIV	X X	X	• The new PLWHIV at Diagnosis • PLWHIV at follow-up visits
Contacts of Bacteriologically confirmed cases	X X	X	• Beginning of treatment of Index case • At the end of treatment of index case
Prison staffs and Prisoners	X X X	X X	• Prison entry point and before leaving prison • In case of a close contact with a TB case • In case of an active Tb campaign drive
Children below 15 years	X X	X	• Malnutrition management centre • Entry to IMCI clinic
Adults above 55 years with Diabetes	X X	X	• At the OPD • At the NCD clinic
The Malnourished	X X	X	• At the Internal Medicine Wards • At the OPD rooms
HCWs and CHWs	X X	X	• Twice per years • Routinely at the OPD
Post-Partum women	X X	X	• During the post natal care
Slum Dwellers and Refuge Camps	X X	X	• During active TB campaign drive • After proper consultation
Alcoholics, Tobbaco and other Drug users	X X	X	• During the general specialized care

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➢ *Prevalence Estimates of Pulmonary Tuberculosis in the Adult Population of Rwanda*

Table 14: Prevalence Estimates of Pulmonary Tuberculosis in the Adult Population of Rwanda

	Number of cases of tuberculosis confirmed by smear in a population of adults (100,000) pop.	**The prevalence of bacteriologically diagnosed Mycobacterium tuberculosis (MTB) per 100,000 adult individuals.**	**Rate of diagnosis for tuberculosis in the adult population based on smear results**
	Estimate (95% CI)	**Estimate (95%CI)**	**Estimate (95%CI)**
Overall	73.2	129.1 (76.7 – 168.8)	0.67 (0.58-1.28)
Sex			
Male	143.9	211.2 (127.7 – 269.8)	0.56 (0.43-0.93)
Female	22.6	53.0 (19.9 – 86.1)	1.54 (0.86-8.61)
Age group			
15-34	56.8	84.7 (51.2 – 123.4)	0.76 (0.66-1.88)
35-54	65.6	123.4 (45.1 – 189.6)	1.22 (0.76-3.87)
54+	158.8	259.9 (106.4 – 421.6)	0.44 (0.33-1.23)