FACTORS ASSOCIATED WITH TUBERCULOSIS AMONG WORKERS IN SOUTH AFRICA: CROSS-SECTIONAL ANALYSIS OF THE NATIONAL INCOME DYNAMICS STUDY, 2017 – 2018

BY

Molele Thandi Celcious

2465337

Research Report Submitted to the Faculty of Health Sciences, University of Witwatersrand in Partial Fulfilment of the degree in Master of Science in Epidemiology in the Field of Epidemiology and Biostatistics

SEPTEMBER 2025

Declaration

I, **Molele Thandi Celcious**, declare that this dissertation is my own. It is being submitted for the Degree of Master of Science in Epidemiology: Epidemiology and Biostatistics at the University of Witwatersrand, Parktown, Johannesburg, South Africa. This work has not been submitted before for any degree or examination at any university.

Student signature

I declare this on 26 September 2025 in Polokwane, South Africa.

Dedication

I am dedicating this research report to the Almighty God for granting me the strength to complete my Master's Degree. I am also dedicating it to my wife, Makoane Molele, for her support throughout the journey. To my child, Dimpho Molele, for being my cheerleader. With unwavering dedication, relentless diligence, and steadfast determination, every aspiration becomes attainable. May this report serve as a testament to the boundless possibilities that lie within your grasp. As you journey through life, embrace this truth and pursue your dreams with unyielding passion.

Abstract

Background

Tuberculosis (TB) is a significant infectious disease that contributes to the worldwide burden of illness. In 2014, the South African government endorsed the End TB initiative, aiming to attain a 90% reduction in TB deaths by 2030. Amid all the strategies in place to reduce TB, it remains an occupational health problem, particularly for individuals who have worked as plant and machine operators. The objective of this study was to describe the socio-demographic characteristics and proportions of tuberculosis among these workers in South African population groups surveyed in 2017.

Methods

A cross-sectional analysis was conducted using Wave 5 of the National Income Dynamic Study dataset, a nationally representative longitudinal household survey conducted in South Africa in 2017. Stratified, two-stage cluster sampling was used to select households, and data were collected through face-to-face interviews to assess multiple dimensions of well-being and social change over time. The outcome variable (TB) was assessed through self-report, based on responses to the health module questionnaire, asking respondents if they had ever been diagnosed with TB. Data were analyzed using descriptive statistics and reported measures of central tendency for continuous variables and frequencies for categorical variables. Bivariate and multivariable analyses were conducted to determine factors associated with TB among workers using a cross-sectional study design in South Africa. Factors included in the final model were age, marital status, province, occupation, household income, BMI, smoking, and HIV/AIDS.

Results

The records of 850 participants were analyzed. The following variables were significant factors associated with TB in the adjusted model: age, marital status, province, occupation, household income, BMI, smoking, and HIV. Participants who were aged between 66 – 70 years had 9.6 times higher odds of reported TB compared to participants aged between 15 – 25 years (AOR = 9.6, 95% CI: 1.8 – 50.1). The adjusted odds of reported TB among participants residing in the Eastern Cape were 3.9 times higher than

the odds of reported TB in those living in Gauteng (AOR = 3.9, 95% CI: 2.0–7.3). Participants who worked as plant and machine operators had 3.7 times higher odds of reported TB compared to participants who worked as professionals, and this difference was statistically significant (AOR = 3.7, 95% CI: 1.7–8.3). Additionally, participants who earned much below average income had 3.9 times higher odds of reported TB compared to participants who earned much above average income (AOR = 3.9, 95% CI: 1.2 – 13.0). The odds of reported TB among participants whose BMI was categorized into being obese (AOR = 0.1, 95% CI: 0.1 – 0.3) were 90% times less compared to participants whose BMI was categorized into being underweight. Participants who self-reported having HIV/AIDS had 2.8 times higher odds of reported TB compared to those who self-reported not having HIV/AIDS (AOR = 2.8, 95% CI: 1.7 – 4.9).

Conclusion

This study found a significant association between age, province, occupation, household income, BMI, HIV/AIDS, and reported TB among study participants. A diagnosis of tuberculosis among workers may adversely affect their work performance, and lead to increased utilization of health care services. This can be addressed by understanding the prevalence of tuberculosis among different occupations, as TB remains an occupational health problem.

Keywords: Tuberculosis (TB), Employed population, South Africa, Occupational Risk Factors, Cross-sectional study, National Income Dynamic Study (NIDS)

Acknowledgements

The Lord is my strength and my shield; in him my heart trusts, and I am helped; my heart exults, and with my song I give thanks *“Psalm 28:7”.*

A special appreciation to my supervisors, Dr Kerry Wilson and Dr Ntombizodwa Ndlovu, for their unwavering support and guidance throughout this process.

I would also like to acknowledge the University of Witwatersrand-School of Public Health, Division of Epidemiology and Biostatistics staff and fellow students.

To my friends and fellow students, thank you for your teamwork, midnight sessions, and calls that gave each other strength and support. I appreciate your contribution; without you, this journey would not have been nearly as successful.

To my wife (Makoane Molele), my mom (Maria Molele), my siblings (Nacos, Danny, and Maphuti), and my child (Dimpho Molele). The support, love, conducive environment, constant prayers, and motivation kept me continuing with the journey. I am grateful for the unwavering love and support.

TABLE OF CONTENTS

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I Molele Thandi Celcious (Student number: 2465337) am a student

registered for the degree of MSc: **Epidemiology and Biostatistics** in the academic year 2025

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.

Signature: ____________________ Date: 20/03/2025

1

.... **Error! Bookmark not defined.**

List of Tables

List of Figures

List of Abbreviations/ Nomenclature

AIDS	Acquired immunodeficiency Syndrome.
DM	Diabetes Mellitus
GBD	Global Burden of Disease
HIV	Human Immunodeficiency Virus
NICD	National Income Dynamic Study
TB	Tuberculosis
SASCO	South African Standard Classification of Occupation
SANTP	South African National Tuberculosis Programme
SDG	Sustainable Development Goals
STATS SA	Statistics South Africa
UN	United Nations
USD	United States Dollar
OR	Odds Ratio
PPE	Personal Protective Equipment
WHO	World Health Organization

CHAPTER 1 – INTRODUCTION

This chapter summarizes the reported tuberculosis (TB) burden among the general population both globally and in South Africa and describes TB in various occupations. The literature review section in this chapter reviews studies that have determined and considered the prevalence and factors associated with TB in the general population and among workers both internationally and locally.

1.1. **Background**

1.1.1. Tuberculosis

Tuberculosis (TB) is a significant infectious disease that contributes greatly to the worldwide burden of illness affecting the general population (Grobler, 2017). It is caused by the bacterium *Mycobacterium tuberculosis* (Koch and Mizrahi, 2018) and typically affects the lungs (pulmonary TB). Simultaneously, extra-pulmonary TB affects other body areas, e.g., the meninges, lymph nodes, joints, and bones. When a person with TB coughs, sneezes, or speaks, droplets (airborne particles) containing the bacteria are released into the air. These droplets can be inhaled by another person, potentially leading to infection with TB (WHO, 2018). Not every person infected with TB develops active TB illness; rather, others might have inactive TB (latent TB).

The End TB strategy, which was developed by the World Health Organization (WHO) and endorsed in 2014, serves as the key approach for countries, including South Africa.
The objectives of the strategy are to attain an 80% decrease in the TB incidence rate and a 90% reduction in TB mortality by 2030 (WHO, 2021). In South Africa, TB continues to represent a severe threat to the country's financial growth, as more than 90% of TB diagnoses and fatalities occur among people of working age. Furthermore, the economic burden is intensified by the significant investment required for tuberculosis prevention, treatment, and control, with global TB funding estimated at $5.8 billion United States Dollars (USD) in 2022 (WHO, 2023). Although strategies are in place to prevent and care

for TB cases, it continues to be one of the biggest causes of illness and mortality worldwide (WHO, 2023).

Although there are TB programs in place to mitigate the burden caused, TB remains a global public health concern. In 2022, 10.6 million people were reportedly diagnosed with the disease, with an incidence rate of 133 per 1000 population in 2022 (WHO,2023). Despite the global strategies in place to end TB by 2030, TB increased by 1.9% between 2020 and 2022 in the general population and continues to be prevalent in low socio-economic and vulnerable populations, which may be due to health-related risk factors and socio-economic determinants (WHO, 2023). To accelerate progress in reducing the TB burden, robust surveillance and intervention must be implemented to attain a 90% decrease in TB incidence rates and a 95% reduction in TB mortality by 2035 (WHO, 2023).

1.1.2. Global burden of Tuberculosis in the general population

Tuberculosis remains a leading cause of death in many countries. Globally, TB accounts for 1.6% of years of life lost and 2.0% of all fatalities, while in South Africa it accounts for 1.6% of years of life lost and 3.8% of deaths (GBD Tuberculosis Collaborators, 2018). In 2015, the Global Burden of Disease study reported that despite preventative measures in place, approximately 1.5 million deaths and 10 million people are infected with TB every year (WHO, 2021). Global TB control efforts are guided by both the United Nations Sustainable Development Goals (SDGs) and the WHO End TB Strategy. The SDGs, adopted in 2015, aim to end the TB epidemic by 2030 as part of a broader commitment to addressing major communicable diseases (UN, 2015). In alignment with this, the WHO End TB Strategy provides a more detailed framework, aiming for substantial reductions in TB incidence and mortality by 2030, with the ultimate goal of eliminating TB as a public health threat by 2035 (WHO, 2014). Together, these strategies highlight the global commitment to TB elimination while emphasizing different timelines and complementary milestones. Nonetheless, TB remains high in both low (e.g., Bangladesh, Pakistan, and Nigeria) and middle-income countries (e.g., India, China, South Africa, Indonesia, and the Philippines) (WHO, 2020).

1.1.3. Tuberculosis in South Africa

In South Africa, the prevalence of TB in the general population was 468 per 100,000 in 2022, with most infections occurring among people in the working-age group (35 to 44 years), at 1,107 per 100,000 population, followed by those in the 65 and above age group, at 1,104 per 100,000 population. The prevalence of TB was the lowest in the age group 15-24 years (432 per 100,000 population) (WHO,2023). TB control in South Africa has improved, yet the disease still has a significant impact. Before the COVID-19 outbreak, tuberculosis was the leading cause of mortality in South Africa in 2018 (Churchyard, 2015).

According to a South African study, those who were previously diagnosed with TB had 7.76 times the odds of developing a recurrent TB compared to those who had no prior history of TB (Kootbodien, 2019). Although the South African government has strong TB control programs, the high rates of TB cases among citizens remain a public health concern, and South Africa remains one of the countries with the highest incidence of TB (WHO, 2023, and Ramaliba *et al*., 2017).

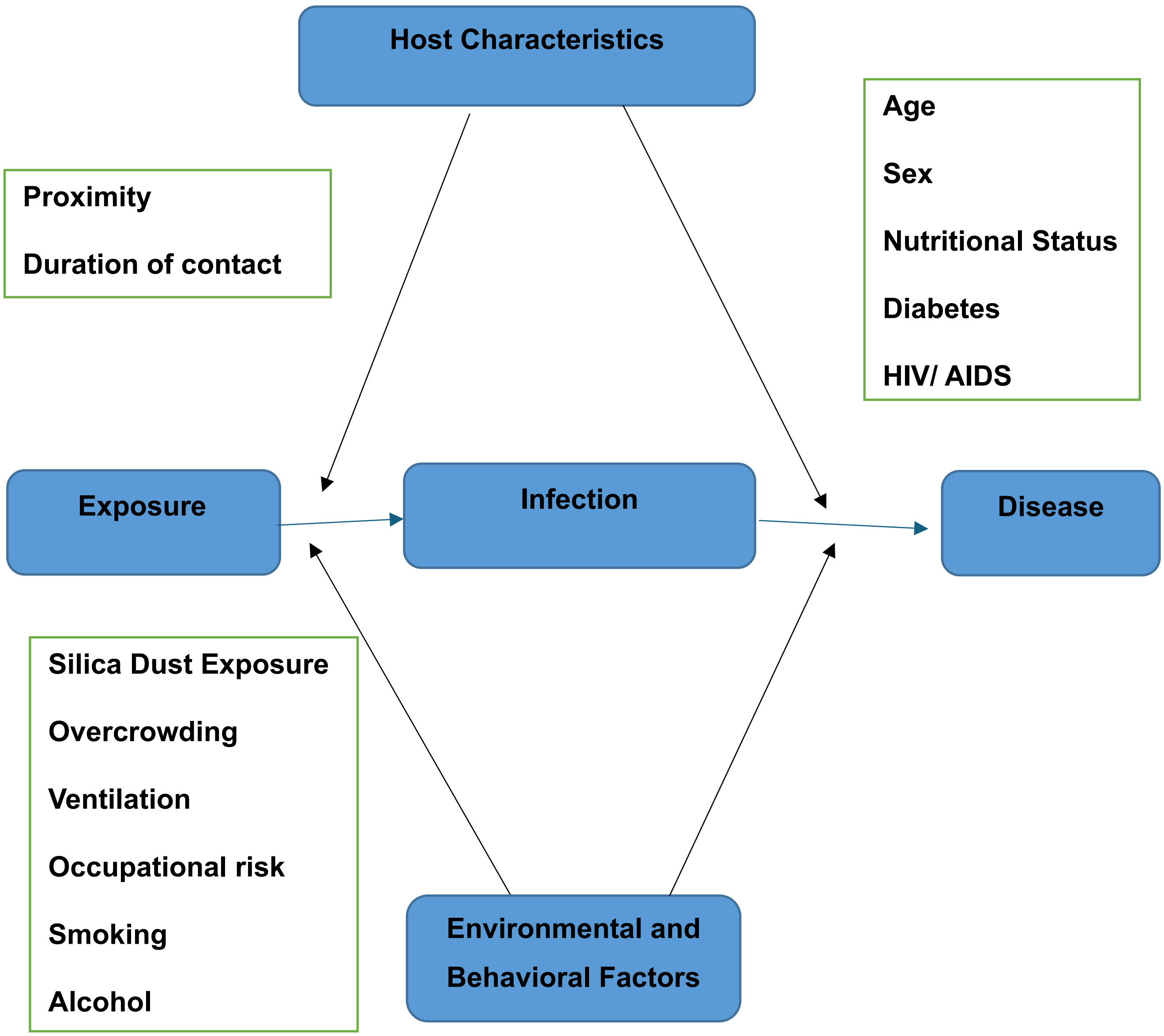
The South African National TB Programme (SANTP) aims to reduce the national incidence of TB to less than 100 per million population by 2035 from 1000 per million population in 2015 (Knight et al., 2015). South Africa has high income disparities, with most of the South African population earning below 2 USD (United States Dollar) per day (Benatar, 2013). Poverty has negatively impacted the well-being of most of the South African population due to their inability to access basic needs of life, like good nutrition (nutritious food), appropriate sanitation, and proper housing, which predisposes them to diseases such as TB (Benatar, 2013).

1.2. Literature review

Several risk factors influence the acquisition of TB infection and the development of active disease. Some are inherent factors (such as age, sex, education, nutrition, marital status, and co-morbidities, mainly HIV/AIDS, and diabetes mellitus), others are environmental factors (crowding, poor ventilation, occupation, proximity, and duration of contact), and behavioral factors (smoking and alcohol intake). The key risk factors for TB infection and death are malnutrition, HIV/AIDS, diabetes mellitus, silica exposure, alcohol, smoking, and indoor air pollution (Narasimhan *et al*., 2013). These factors are not isolated and may occur simultaneously, increasing risk profiles.

Conceptual Framework

The conceptual framework depicted in Figure 1 illustrates the multilevel factors associated with TB among workers in South Africa. This framework guided the selection and extraction of variables of interest from the National Income Dynamic Study (NIDS) to answer the research question for this study. The conceptual framework shows the possible exposure variables associated with TB among workers in South Africa. The exposure variables include the inherent, environmental, and behavioral risk factors that may be associated with TB among workers in South Africa.



Taken from: (Narasimhan *et al.*,2013)

Figure 1: Risk factors associated with Tuberculosis infection.

1.2.1. Inherent Risk Factors

1.2.1.1. Age and TB Risk

Respiratory disorders, such as TB, are remarkably more common in the aged population, which is due to age-related impaired lung physiology from changes in the cellular and structural makeup across the respiratory epithelium (Lowery *et al*., 2013). Lowery et al (2013) further indicate that as one ages, lung function gradually deteriorates, leading to reduced respiratory muscle strength, vital capacity, and force expiratory capacity. Age is considered a risk factor for TB, with elderly individuals more vulnerable to TB infections, particularly due to the weakening of the immune system, which helps fight against infections (Byng-Maddick and Noursadeghi, 2016).

TB affects people of all age groups, but the highest burden is in individuals aged 25 to 54 years (WHO, 2023). However, in South-East Asia and the Western Pacific, TB was mostly prevalent in individuals aged 65 years and above (Byng-Maddick and Noursadeghi, 2016). In France in 2019, among the elderly, TB was highest (17.5%) among individuals who were >65 years old, followed by 9.8% in the >75 years group, and the fewest cases were reported in >80 years with 6.3% of the cases reported in this cohort (Caraux-Paz *et al*., 2021). A 2010 study on a migrant community residing in Baja California, Mexico, found that the odds of TB were similar, 1.03 (95% CI 1.00 -1.07) for individuals who were younger (18-29 years) and older age (≥ 30 years) (Garfein *et al*., 2010).

1.2.1.2. Nutritional Status and TB Risk

Nutrition plays a vital role in boosting the immune system to fight bacterial and viral infections (Caraux-Paz *et al*., 2021). Undernutrition is defined as inadequate intake of nutrients and energy to meet the daily dietary requirements of an individual, resulting in impaired absorption and utilization of nutrients (Maleta, 2006; Sahile *et al*., 2020). Undernutrition is the second leading cause of immunodeficiency globally and compromises both innate and adaptive immune responses, thereby weakening the body's ability to control tuberculosis infection (Bhargava, 2016; Sinha *et al*., 2019). The World Health Organization (2021) estimates that undernutrition is the leading risk factor for tuberculosis, contributing to approximately 19% of the global TB burden in endemic countries. Individuals with poor socio-economic status are particularly vulnerable, as poverty contributes to both inadequate nutrition and greater susceptibility to infectious diseases, resulting in poorer prognosis (Murray and Oxlade, 2012).

Evidence further indicates that undernourished individuals are 3.2 times more likely to develop TB compared to those who are adequately nourished (Diaz, 2017). Patients with tuberculosis experience malnutrition due to decreased appetite, malabsorption of micronutrients, and altered metabolism, resulting in persons being underweight (Feleke *et al*., 2019, and Gupta *et al*., 2009). Given that malnutrition raises the risk of receiving a TB diagnosis, a study on the nutritional state of TB patients revealed a bidirectional rather than one-way relationship between nutrition and tuberculosis (Feleke *et al*., 2019, and Gupta *et al*., 2009).

1.2.1.3. HIV/ AIDS and TB Risk

HIV/AIDS is ranked the second-highest risk factor for TB with a population-attributable fraction (PAF) of 7.6% for TB (WHO, 2021). Studies conducted in South Africa, Lesotho, and Mozambique have shown that individuals living with HIV face a substantially elevated risk of developing active tuberculosis, ranging from 5% to 20%, compared to only 0.2% among HIV-negative individuals (Maher *et al*., 2005; Glaziou *et al*., 2018). In the South African context, HIV/AIDS is an important risk factor for TB. The prevalence of HIV/AIDS infection is high (19.1 per 100 population), and people who are HIV infected are 18 times more likely to get tuberculosis than those who are HIV uninfected (WHO, 2021). The World Health Organization (WHO) reported that in South Africa, TB fatalities among HIV-positive people in 2022 were 31,000, and the impacts are forecasted to be much worse in the upcoming years (WHO,2023).

Among health care workers, the odds of contacting TB are 6.35 for individuals who were diagnosed with HIV than those who were HIV negative, and it was further indicated that the risk among health care workers who are living with HIV was more than 20 times than those who were not living with HIV which puts individuals living with HIV at a greater risk of being diagnosed with TB (Tudor *et al*.,2016).

1.2.1.4. Diabetes Mellitus and TB Risk

Diabetes mellitus (DM) is one of the risk factors for the development of TB as it compromises immunity (Rieser, 2014). Diabetes mellitus is the third highest global risk factor for TB, with a population-attributable fraction of 3.1% (WHO, 2020). Individuals who have diabetes are 1.5 times more likely to develop TB compared to individuals without diabetes (WHO, 2021). In a prospective cohort of patients who were diagnosed with TB and DM, smear-positive culture rates of 22.2% were seen in DM patients, while 6.9% were reported in patients without DM (Alisjahbana *et al*., 2006). The study conducted in South Africa reported that the high prevalence of DM increases alongside the high prevalence of communicable diseases (CDs), including TB (Kumar and Babu, 2017).

1.2.2. Behavioral Risk Factors

1.2.2.1 Smoking and TB Risk

Negative prognosis of TB has also been linked to cigarette smoking (Feldman *et al*., 2024). According to the WHO, about 1.3 billion people globally use tobacco, with approximately 80% or more of these smokers residing in low-and middle-income countries. It was further reported that of the 22.3% of the global population that were tobacco users, men were the highest tobacco users (36.7%) compared to women (7.8%) (WHO, 2021). This widespread tobacco use is particularly concerning given the established link between smoking and TB outcomes.

Tobacco smoke alters mucociliary clearance through modifying the lung's defenses against tuberculosis infection, increasing the risk of tuberculosis (Underner and Perriot, 2012). Tuberculosis impairs macrophage activation, a process essential for mounting an effective immune response against pathogens. Smoking further compromises the immune system and causes extensive damage to multiple organs, particularly the lungs, thereby increasing susceptibility to TB among smokers compared with non-smokers (Amere *et al*., 2018).

In a meta-analysis focusing on Indian women, researchers reported that cigarette smokers had a higher relative risk of TB disease (RR = 2.5; 95% CI 2.3 – 2.7) compared to non-smokers (Bates *et al*., 2007). Several reviews have concluded that smoking is strongly linked to increased incidence of both tuberculosis infection and tuberculosis illness (Alexander *et al*., 2022; Nel *et al*.,2019; Alavi-Naini *et al*.,2012). In a multivariate logistic regression, cigarette smokers had higher odds of TB disease (OR = 3.1; 95% CI 1.4 – 10) compared to non-smokers (Alavi-Naini *et al*.,2012). A study on survival analysis for participants with TB in China discovered that participants who were smokers had thrice the risk of TB compared to non-smokers (OR 3.4, 95% CI 1.7 – 7.0) (Carter *et al*., 2021).

1.2.2.2. Alcohol Use and TB Risk

Harmful alcohol consumption weakens the immune system, increases susceptibility to tuberculosis infection, and adversely affects treatment outcomes (Lönnroth *et al*., 2008; Rehm *et al*., 2009). Globally, alcohol abuse is responsible for an estimated 2.6 million deaths annually, accounting for 4.7% of all fatalities (WHO, 2018). Wigger *et al*. (2022) reported that more than 8% of tuberculosis cases globally are attributable to alcohol abuse. Alcohol misuse impairs alveolar macrophage function by inhibiting cytokine release, thereby weakening immune responses against TB. This immune suppression not only increases vulnerability to infection but also heightens the risk of latent TB reactivation (Wigger *et al*., 2022). Chronic alcohol intake weakens the immune functions, particularly the phagocytic capacity of the alveolar macrophage, which is essential for the lung's natural innate immunity and the lower respiratory tract's first line of defense against TB (Diaz, 2017).

Consuming alcohol, especially in large amounts (more than four drinks on any day in men and three in women), is a significant risk factor for TB as alcohol can damage the immune system and increase vulnerability to infection (Bhat *et al*., 2017). Individuals who were using alcohol were 3.3 times more likely to develop TB compared to individuals who were not using alcohol (WHO, 2021). It is further reported that consumption of alcohol increases the likelihood of TB threefold, whilst smoking increases the risk by 1.6 (Diaz, 2017).

1.2.2.3. Environmental Risk Factors for TB

The environment has a significant influence on the development and progression of tuberculosis, with overcrowding and inadequate ventilation increasing the risk of being exposed to TB (Narasimhan *et al*., 2013). Poorly ventilated houses, overcrowding, and undernutrition that result from socio-economic deprivation increase the likelihood of developing TB by increasing the risk of exposure to an infected person and by making people more susceptible to infection (Pedrazzoli, 2017). In a multivariate analysis focusing on silica dust exposure, it was discovered that those who were exposed to silica dust had higher odds of TB disease (OR = 10.2; 95% CI 2.1 – 50.1) compared to those who were not exposed to silica dust in Johannesburg, South Africa (Kootbodien *et al*., 2019).

1.2.2.4. Occupational Exposure and TB Risk

Tuberculosis is an occupational health problem, particularly in specific working environments (WHO,2023). Although TB is an underreported occupational disease in South Africa, healthcare workers and silica-exposed employees are more likely than other occupations to experience an incident of TB due to the nature of their work (Rosenman and Hall, 1996). Workers in specific industries are at elevated risk due to both environmental exposures and prolonged contact with infectious patients. Among these industries, silica-exposed occupations such as mining, quarrying, and stone processing have consistently been identified as high-risk, with exposure to silica dust significantly increasing susceptibility to TB (Hnizdo and Murray, 1998; Ehrlich et al., 2021).

Healthcare workers also face a disproportionate burden of TB, mainly attributable to frequent and extended contact with patients. Within hospitals, nurses and cleaning staff have been found to carry the most significant risk, the latter being particularly vulnerable due to extended exposure to infectious environments (Grobler et al., 2016). Contributing factors include inconsistent use of personal protective equipment (PPE), job type, and work location, which can further heighten vulnerability among health professionals (Hnizdo and Murray, 1998). Beyond these well-studied groups, evidence from national mortality data indicates elevated TB-related deaths among other occupational categories, including agricultural and fishery workers, machine operators, and production line staff (Hnizdo and Murray, 1998). However, research on TB risk outside of mining and healthcare sectors remains limited.

Expanding occupational surveillance and monitoring could provide a more comprehensive understanding of TB burden across diverse industries, detect emerging trends, and strengthen targeted prevention programmes. To facilitate such surveillance, the South African Standard Classification of Occupations (SASCO) offers a structured framework for grouping jobs by skill level and type of work (Statistics South Africa, 2012). Using SASCO in TB research not only ensures systematic comparisons across occupational groups but also enhances the alignment of research findings with national labour statistics, thereby improving their policy relevance.

1.2.2.5. Workplace Exposure and TB Risk

Tuberculosis is prevalent among health care workers and workers exposed to silica dust, reducing the labour force due to poor health compared to non-exposed individuals. A study published in the National Library of Medicine found that silica-exposed workers, whether or not they have silicosis, are at an elevated risk of tuberculosis and nontuberculous mycobacteria-related disorders (Ehrlich *et al*., 2021). The study reported that, while the strength of association between occupations and industries and TB varied, nonmetallic mineral and stone products faced a heightened risk of TB, followed by quarrying and those working in eating and drinking establishments (Rosenman and Hall, 1996). In 1998, It was reported that the relative risk of having TB following silica exposure is 1.1 times the risk of not being exposed to silica (Hnizdo and Murray, 1998), however, in a meta-analysis focusing on silicosis exposed individuals, it was discovered that, the relative risk of having TB disease following silica exposure had higher risk (RR = 4.01; 95% CI 2.88 – 5.58) (Ehrlich *et al*., 2021).

There is a higher prevalence of TB in healthcare workers compared to other professions (Malangu and Legothoane, 2013). It was reported that TB was the most commonly reported hospital-acquired infectious disease, at 83.9% (47 of 56), followed by cholera at 10.6% (6 of 56) and chickenpox at 5.4% (3 of 56) in hospitals in Limpopo Province. However, it is regarded as an underreported occupational disease in South Africa (Malangu and Legothoane, 2013). Workplace-acquired TB is a significant occupational concern for South African health care workers (Grobler *et al*., 2016). It was further reported that, among professional staff in hospitals in Limpopo Province, nurses 63.8% (30 of 47) were the mostly affected by TB as compared to other medical staff 1.8% (1 of 47), while cleaning staff were most affected 17% (8 of 47), compared to other hospital non-professional staffs namely; administrative clerks 8.5% (4 of 47), kitchen staff 4.3% (2 of 47) drivers and maintenance staff 2.1% (1 of 47) (Malangu and Legothoane, 2013). Cleaning staff were more susceptible to TB infection compared to other non-medical staff due to the duration of contact with TB-infected patients (Grobler *et al*., 2016). The prevalence of TB is higher among healthcare workers (23.4, 95% CI 22.5 to 24.4) compared to non-healthcare workers (16.2, 95% CI 16.0 to 16.3) per 100,000 population (Davidson et al., 2017; O'Hara *et al*., 2017). It was reported that, apart from health care workers, there was a higher TB death rate among agricultural workers as compared to business and administrative professions, which may be attributable to difficulties in accessing healthcare facilities (Kootbodien *et al*., 2018).

1.2.3. NIDS and TB

The World Health Organization (WHO) encourages countries to conduct TB prevalence surveys for the WHO to inform global estimations of TB burden (Pillay *et al*., 2021). The National Income Dynamics Study (NIDS) is conducted every two years and is the first national dynamic structure of household panel study in South Africa. It is part of an intensive multi-million-rand effort to trace and understand the changing face of poverty and well-being. NIDS collects comprehensive information on socio-demographic characteristics, income, education, employment, health status, and access to healthcare, which are all critical determinants of TB risk and treatment outcomes. The longitudinal design enables the exploration of associations between TB and social, economic, and occupational factors over time, providing insights into causal pathways and long-term effects. Additionally, NIDS is particularly suited for TB-related research because it captures data on self-reported TB diagnosis alongside key covariates such as HIV status, undernutrition, smoking, alcohol use, and province of residence, all of which are established risk factors for TB. Its nationally representative sampling frame enhances the generalizability of findings, while the large sample size provides adequate statistical power for subgroup analysis. The NIDS uses the South African Standard Classification of Occupations (SASCO), a standardized approach developed to guarantee uniformity in characterizing and evaluating employment across industries, to classify occupational data in South Africa (Statistics South Africa, 2012). SASCO makes it possible to systematically investigate relationships between disease outcomes, job status, and occupational groups.

1.3. Problem Statement

TB remains one of the most common infectious disease-related causes of death globally, and it poses a danger to the country's financial prosperity (WHO, 2023). Despite international efforts to eliminate tuberculosis, as more than 90% of TB diagnoses and fatalities occur among persons of working age, TB remains an occupational health problem, especially in specific work environments, and it is an underreported occupational disease in South Africa (Malangu and Legothoane, 2013). Tuberculosis was the most frequently reported hospital-acquired infectious disease compared to other hospital-acquired contagious diseases, such as cholera and chickenpox (Holmes *et al*., 2017). Evidence from rural health districts, such as Mopani in Limpopo Province, shows that younger nurses are particularly vulnerable to TB infection (Malangu and Legothoane, 2013; Grobler et al., 2016). Beyond nurses, other categories of hospital workers are also affected, with cleaning staff being mostly affected by TB compared to other non-medical staff due to the duration of contact with TB-infected patients (Grobler *et al*., 2016). Beyond healthcare and mining, national mortality data further highlight TB-related risks in other sectors, including agricultural and fishery workers, production line staff, and machine operators (Hnizdo and Murray, 1998).

These patterns suggest that TB vulnerability is not confined to well-studied groups but extends across multiple occupational categories, often influenced by working conditions, job type, and access to protective measures. However, research outside the healthcare and mining sectors remains limited, underscoring the need for more comprehensive surveillance. The South African Standard Classification of Occupations (SASCO) provides a structured framework for comparing occupational risk across diverse sectors, enabling identification of high-risk groups and alignment of research findings with national labour statistics (South African Standard Classification of Occupations, 2012). Addressing the problem of occupational TB underreporting by researching different occupations is critical for improving outcomes and reducing the spread of tuberculosis. This research aims to estimate TB proportions and factors associated with occupation across different SASCO occupation groups in the South African population in 2017.

1.4. Justification

The existence of large population-based datasets that include information on employment and disease, such as the National Income Dynamics Data (NIDS data), provides an opportunity to investigate the national TB proportions and factors associated with TB among workers in South Africa. The findings will generate evidence on the socio-demographic, occupational, and geographic factors associated with TB prevalence among workers, offering a detailed understanding of how employment influences disease burden. This information is critical for informing workplace-specific infection-control protocols, designing targeted prevention and health education interventions, and guiding active case-finding policies in high-risk sectors. Reducing TB in workplaces can lower both direct costs, such as healthcare spending on diagnosis and treatment, and indirect costs, including productivity losses, absenteeism, and staff turnover. By identifying high-risk occupational groups and the factors associated with TB, the study's findings can inform workplace-level prevention programs, strengthen occupational health policies, and support national TB control strategies, thereby contributing to South Africa's efforts to meet global targets for ending TB by 2035 (Grobler et al., 2016).

1.5. Research question

What are the socio-demographic, occupational, and health-related factors associated with tuberculosis prevalence among workers in South Africa, as identified through a cross-sectional analysis of the National Income Dynamics Study in 2017?

1.6. Aim

The study aims to identify factors associated with tuberculosis among workers in the South African population in 2017.

1.7. Objectives

1. To describe the socio-demographic characteristics and proportions of tuberculosis among workers in the South African population groups surveyed in 2017.
2. To map TB proportions by occupation among workers in the South African population groups in 2017.
3. To determine the association between TB and occupation groups among South African workers in 2017.

CHAPTER 2 – METHODS

2. Chapter Outline

This chapter gives a summary of the research methods of the study. This chapter begins by describing the study design and data collection methods used in the NIDS study, followed by a detailed explanation of the methodology used in the current study.

2.1. Description of primary study

This study utilized data from the National Income Dynamics Study (NIDS), a national panel study conducted in South Africa and initiated by the Southern African Labour and Development Research Unit. The mandate is to assess the livelihoods of individuals and households over time and provide information on population demographics, levels of education, income dynamics, health, social well-being, and socioeconomic status using a stratified, two-stage cluster design to sample households in waves between 2008 and 2017. The primary study sampled a total of 31,144 participants, where 10,367 households were selected from 400 primary sampling units throughout South Africa. Among these participants, 28,226 were considered eligible by the inclusion criteria (being South African residents) and had given consent to participate in the NIDS study (South African Labour and Development Research Unit, 2008). The sample size for the panel study was approximately 28,000 people from 7,300 families across the country. To be included in the study, a household member should reside at the house four nights a week. The study design of the primary study was repeated cross-sectional surveys. The purpose of each survey was to assess the livelihoods of individuals and households, providing information on population demographics, levels of education, income dynamics, health, social well-being, and socioeconomic status.

The primary study integrated both cross-sectional and longitudinal data (prospective cohort) to understand the current state and changes over time in 2017. The same households were approached as in previous NIDS survey waves, which were selected using a stratified, two-stage cluster design from 2008 to 2018 throughout South Africa. To date, no research has been conducted using this dataset to examine the prevalence of reported TB among workers.

The surveys were conducted in all nine provinces of South Africa. The first wave (Wave 1) of the study was conducted in 2008, while Wave 5 was conducted in 2017. Data in the surveys were collected using uniform questionnaires, which were first pre-tested and then administered in two provinces, Gauteng and KwaZulu-Natal, before rolling out to other provinces. The NIDS defined household income based on a household's ability to progress up the income ladder and the probability of falling back down the income ladder (Daniels *et al*., 2022). The study was mainly suitable for TB among workers because of the detailed collection of information on occupation.

2.2. Study design

This was a cross-sectional study using secondary data from the 2017 NIDS Wave five survey.

2.3. Study site

This study included all nine provinces in South Africa, with samples from rural and urban areas.

2.4. Study population

All adult participants (aged 15 years and older) from the NIDS dataset who reported being in any form of pre-defined employment were included in this study. Age was categorized into eleven groups: 15–25, 26–30, 31–35, 36–40, 41- 45, 46- 50, 51- 55, 56- 60, 61- 65, 66- 70, and 71-75. This categorization reflects both epidemiological evidence and practical considerations in the dataset. Tuberculosis risk is highest among individuals in their economically active years, particularly those aged 25–54 years, who represent the most significant proportion of the South African workforce (WHO, 2023). Grouping participants into these categories allows for meaningful comparisons across different stages of working life, while minimizing small cell sizes in the analysis. Furthermore, these age groupings are consistent with national reporting frameworks and previous South African studies on TB and occupational health (Shisana *et al*., 2014; Kootbodien *et al*., 2018). Using standardized categories ensures comparability with existing surveillance data and facilitates interpretation of occupational TB risk in relation to age.

Employment was defined broadly to capture individuals in formal employment, informal employment, or self-employment. For this analysis, only participants who were employed during Wave 5 (2017) were selected, as this wave represents the most recent and comprehensive dataset, ensuring both recency of information and sufficient coverage of variables related to employment, socioeconomic factors, and self-reported TB.

2.5. Sampling

The 2017 NIDS dataset was obtained from the NIDS website (http://nids.uct.ac.za) after receiving approval from the gatekeepers. Sampling was already conducted as part of NIDS, and no further sampling was done for the current study. The reported tuberculosis (TB) prevalence among the working population was estimated at 0.014, derived by doubling the reported TB prevalence in the general population (737 per 100,000, equivalent to 0.007) to ensure the study retains sufficient statistical power. This adjustment served as a conservative estimate to account for industries with a higher reported TB burden.

The primary NIDS Wave 5 dataset included 28,226 eligible participants, of which 5,109 were retained for this analysis. The reduction in sample size reflects the study's inclusion criteria, where only adult participants (≥15 years) who reported being employed (formally, informally, or self-employed) during Wave 5 were included. Unemployed participants, not of working age, or with missing data on key variables were excluded. A power calculation was conducted in Stata using the sampsi command as follows: **sampsi 0.014 0.007, n (5109) onesam,** which gave the power of 99.94% **(Appendix II).**

2.6. Exclusion criteria

The study excluded individuals under 15 years of age because, according to the Basic Conditions of Employment Act, it is a criminal offense to employ a child younger than 15, and they are not legally permitted to work (Saica, 2015). Individuals over 75 years of age were also excluded, as most workers in corporate roles retire at 75 in South Africa (Saica, 2015).

2.7. Variables

Occupations were classified using the South African Standard Classification of Occupations (SASCO) (StatsSA, 2012). The independent variables were socioeconomic status, household size, income level, age, sex, educational level, province, nutritional status, and comorbidities (including HIV/AIDS and diabetes mellitus). Furthermore, employment status (e.g., employed, unemployed), occupation (which specifies the type of work aligned with SASCO classifications), and the Sector employed in (which describes the industry of employment). In contrast, the dependent variable was Tuberculosis (Appendix II).

2.8. Data source

Data for Wave 5 (2017) were downloaded from the National Income Dynamic Study (NIDS) website for analysis after obtaining access. The NIDS survey comprises four main questionnaires: Household, Adult, Child, and Proxy Questionnaires. For this study, only the adult questionnaire was used. The children's questionnaires were excluded since children form part of the exclusion criteria, and the Household and Proxy questionnaires were excluded as they did not focus on individual health and demographics.

2.9. Data Collection Procedures

The data was extracted as a CSV file and then imported into STATA 17 for cleaning and analysis (StataCorp, 2021). Data was securely saved on a computer with a password-protected external hard drive and backed up on a CD drive and Google Drive. The missing values were assessed using descriptive statistics, and missing values were coded consistently (not stated). Duplicate observations were identified and removed. Recoding of variables was performed to align with the study framework, for example, categorizing occupations using the South African Standard Classification of Occupations (SASCO) and grouping provinces for geographic comparisons. For spatial analysis and mapping, cleaned data were exported and linked with provincial shapefiles. This process was performed using FME Workbench (formerly known as Feature Manipulation Engine, FME) for data processing and integration, and QGIS for visualization of TB distribution across South African provinces. Data quality in NIDS was ensured through rigorous procedures, including the training and supervision of fieldworkers, the use of standardized and piloted questionnaires, computer-assisted data entry with built-in consistency checks, and repeated call-backs to households to minimize missing or inaccurate responses.

2.10. Data analysis

Objective 1: To describe the socio-demographic characteristics and proportions of historical tuberculosis among workers in the South African population groups surveyed in the 2017 NIDS study.

Descriptive statistics were used to summarize the socio-demographic data. Measures of central tendency were used for continuous variables, and frequencies were reported for categorical variables. Pearson's Chi-square test was used to test for a significant difference in proportions of reported TB as frequencies and proportions expressed as percentages (%).

Objective 2: To map TB prevalence by occupation in the South African population in 2017.

The mapping of TB by occupation using the NIDS Wave 5 dataset in South Africa was produced using the ArcGIS Pro software. Spmap was used to visualize various types of spatial data, and it is especially well-suited for creating thematic maps and exhibiting the results of spatial data analyses (Pisati, 2007). The NIDS data was merged with the province shapefile of South Africa, and it was aggregated based on occupation only and based on occupation and province. The occupation aggregation was displayed in the form of a choropleth map, where occupations and provinces were represented by rings based on their counts, illustrating the distribution of reported TB by occupation and the distribution of TB across the nine provinces of South Africa. Different colors were used to represent various occupations.

Objective 3: To determine the association between TB and occupation groups among South African workers in 2017.

The associations between reported TB and exposure variables were initially assessed using bivariate logistic regression analysis. The bivariate logistic regression analyses estimated the unadjusted measures of association as crude odds ratios (cOR), along with the p-value and the corresponding 95% confidence interval (CI). All exposure variables with odds ratios (ORs) that were significant at $p \leq 0.2$ were included in the multivariate logistic regression using the backward stepwise elimination process. Variables with $p < 0.05$ in the multivariate model were considered significant. Based on prior knowledge, diabetes was included in the multivariate logistic regression analysis; however, it did not improve the final model and was subsequently removed from the analysis. Although marital status was not statistically significant, it was included in the final model since it improved the model. The final model's output, the adjusted odds ratios (aOR), p-values, and 95% confidence interval (CI) were estimated and reported. The model fit was assessed using information criteria (AIC and BIC) for the selection of the best model, and a p-value of <0.001 was considered to indicate that the model fit represented the observed data well. Furthermore, the goodness-of-fit test produced a p-value of 0.5528, indicating that the model adequately fits the data. A p-value above 0.05 suggests that the model is appropriate for explaining the relationship between occupation and TB (Appendix III).

2.10. Ethical considerations

The primary study obtained ethical approval from the National Health Research Ethics Committee (NHREC), the Stellenbosch University Research Ethics Committee, the Social, Behavioral, and Educational Research (SBER) Committee, and the University of Cape Town Research Ethics Committee (UCT). Permission to access the data was obtained from gatekeepers (NIDS). For this study, ethical approval for secondary data analysis was obtained from the Wits Human Research Ethics Committee (Medical) (Clearance certificate number: W-PR-231129-01). (Appendix I).

CHAPTER 3 – RESULTS

3. Chapter Outline

This chapter presents the results according to the following order: descriptive table of demographic factors and association with tuberculosis, mapping of reported TB among different occupations according to SASCO groups, and factors associated with tuberculosis and factors related to tuberculosis among other occupations in NIDS. TB status was self-reported based on prior diagnosis, rather than confirmed through clinical records or laboratory tests.

3.1 Description of Participants

Table 1 shows the description of study participants. There were 23,184 participants in the study. Most were female (n=13, 729, 59.2%) and were between 15 to 25 years of age (n=7, 392, 31.9%). The number of study participants decreased consistently with an increase in age. Households were sampled on race, and participants' race reflected the race distribution for South Africa. In terms of marital status, most respondents were not married (n=13,125; 64%). Less than half (46.9%) of the participants earned an average household income, and only 3.2% earned a significantly higher household income. In the industrial sector groups of employed participants, most respondents were those who worked under community, social, and personal services (n=1,999; 30.0%). (Table 1) A total of 850 (3.7%) reported having had TB.

Table 1: Demographic factors in the number and percentage of the category and their crude association with tuberculosis

		TB		
		Yes	No	P-value*
		N (%)	N (%)	

Number	Total N = 23 184 (%)	850	22,334	
Sex				
Female	13 729 (59.2)	447 (3.3)	13 282(96.7)	**<0.001**
Male	9 455 (40.8)	403 (4.3)	9 052 (95.7)	
Age Category				**<0.001**
15 – 25	7 493 (32.3)	101 (1.4)	7 392 (98.6)	
26 – 30	2 839 (12.2)	74 (2.6)	2 765 (97.4)	
31 – 35	2 384 (10.3)	100 (4.2)	2 284 (95.8)	
36 – 40	1 705 (7.4)	89 (5.2)	1 616 (94.8)	
41 – 45	1 609 (6.9)	119 (7.4)	1 490 (92.6)	
46 – 50	1 426 (6.2)	96 (6.7)	1 330 (93.3)	
51 – 55	1 415 (6.1)	68 (4.8)	1 347 (95.2)	
56 – 60	1 278 (5.5)	79 (6.2)	1 199 (93.8)	
61 – 65	1 038 (4.5)	54 (5.2)	984 (94.8)	
66 – 70	785 (3.4)	33 (4.2)	752 (95.8)	
71 – 75	502 (2.2)	16 (3.2)	486 (96.8)	
Not Stated	710 (3.1)	21	689	
Race				**<0.001**
African	18 538 (80.0)	673 (3.6)	17 865 (96.4)	
Coloured	3 076 (13.3)	167 (5.4)	2 909 (94.6)	
Asian/Indian	381 (1.6)	3 (0.8)	378 (99.2)	
White	1 182 (5.1)	7 (0.6)	1 175 (99.4)	
Not Stated	7 (0.0)	7	0	
Marital Status				**0.003**

Not Married	13 125 (56.6)	429 (3.3)	12 696 (96.7)	
Married or Living with Partner	7 382 (31.8)	300 (4.1)	7 082 (95.9)	
Not Stated	2 677 (11.5)	121	2 556	
Educational Status				**<0.001**
No schooling	1 649 (7.1)	85 (5.2)	1 564 (94.8)	
Primary education	3 885 (16.8)	256 (6.6)	3 629 (93.4)	
Secondary education	17 534 (75.6)	502 (2.9)	17 032 (97.1)	
Post-metric education	58 (0.3)	3 (5.2)	55 (94.8)	
Not Stated	58 (0.3)	4	54	
Province of Residence				**<0.001**
Western Cape	2 531 (10.9)	107 (4.2)	2 424 (95.8)	
Eastern Cape	2 585 (11.1)	166 (6.4)	2 419 (93.6)	
Northern Cape	1 718 (7.4)	88 (5.1)	1 630 (94.9)	
Free State	1 264 (5.5)	35 (2.8)	1 229 (97.2)	
KwaZulu-Natal	6 701 (28.9)	252 (3.8)	6 449 (96.2)	
Northwest	1 419 (6.1)	75 (5.3)	1 344 (94.7)	
Gauteng	3 229 (13.9)	59 (1.8)	3 170 (98.2)	
Mpumalanga	1 742 (7.5)	41 (2.4)	1 701 (97.6)	
Limpopo	1 995 (8.6)	27 (1.4)	1 968 (98.6)	
Employment Status				**<0.001**
Employed	6 642 (28.6)	236 (3.6)	6 406 (96.4)	
Unemployed	5 032 (21.7)	205 (4.1)	4 827 (95.9)	
Self-employed	1 127 (4.9)	38 (3.4)	1 089 (96.6)	
Casual work	858 (3.7)	60 (7.0)	798 (93.0)	

Subsistence farming	155 (0.7)	6 (3.9)	149 (96.1)	
Assist in business	81 (0.3)	4 (4.9)	77 (95.1)	
Retired or over 65 years of age	3 051 (13.2)	130 (4.3)	2 921 (95.7)	
Student	3 761 (16.2)	37 (1.0)	3 724 (99.0)	
Home maker or childcare	1 638 (7.1)	49 (3.0)	1 589 (97.0)	
Sick or living with disability	704 (3.0)	81 (11.5)	623 (88.5)	
Pregnant	130 (0.6)	4 (3.1)	126 (96.9)	
Not Stated	5 (0.0)	0	5	
Occupation for Employed				**<0.001**
Agricultural, forestry, and fishery laborers	39 (0.2)	1(2.6)	38 (97.4)	
Armed forces	10 (0.0)	1 (10.0)	9 (90.0)	
Clerical support	320 (1.4)	6 (1.9)	314 (98.1)	
Crafts and trade workers	685 (3.0)	25 (3.7)	660 (96.3)	
Elementary occupation	1 890 (8.2)	107 (5.7)	1783 (94.3)	
Managers	312 (1.3)	6 (1.9)	306 (98.1)	
Plant and machine operators	616 (2.7)	38 (6.2)	578 (93.8)	
Professionals	798 (3.4)	13 (1.6)	785 (98.4)	
Service and sales	1 079 (4.7)	25 (2.3)	1 054 (97.7)	
Technicians and associates	379 (1.6)	5 (1.3)	374 (98.7)	
Not Stated	17 056 (73.6)	623	16 433	
Household Income				**<0.001**
Much Below Average	3 603 (15.5)	193 (5.4)	3 410 (94.6)	

Below Average	5 635 (24.3)	234 (4.2)	5 401 (95.8)	
Average Income	10 538 (45.5)	336 (3.2)	10 202 (96.8)	
Above Average	1 980 (8.5)	45 (2.3)	1 935 (97.7)	
Much Above Average	721 (3.1)	18 (2.5)	703(97.5)	
Not Stated	707 (3.0)	24	683	
The sector employed in				**0.002**
Agriculture, hunting, forestry and fish	746 (3.2)	42 (5.6)	704 (94.4)	
Community, social, and personal services	1 999 (8.6)	69 (3.5)	1 930 (96.5)	
Construction	390 (1.7)	20 (5.1)	370 (94.9)	
Electricity, gas, and water supply	85 (0.4)	4 (4.7)	81 (95.3)	
Financial intermediation, insurance	603 (2.6)	9 (1.5)	594 (98.5)	
Manufacturing	718 (3.1)	21 (2.9)	697 (97.1)	
Mining and quarrying	274 (1.2)	11 (4.0)	263 (96.0)	
Private households	515 (2.2)	24 (4.7)	491 (95.3)	
Transport, storage, communication	269 (1.2)	6 (2.2)	263(97.8)	
Wholesale and retail trade	1 061 (4.6)	31 (2.9)	1 030 (97.1)	
Not Stated	16 524 (71.2)	613	15 911	
BMI Category				**<0.001**
Underweight	1 742 (7.5)	135 (7.8)	1 607 (92.2	
Normal	9 485 (40.9)	424 (4.5)	9 061 (95.5)	
Overweight	5 191 (22.4)	146 (2.8)	5 045 (97.2)	

Obese	6 257 (27.0)	130 (2.1)	6 127 (97.9)	
Not Stated	509 (2.2)	15	494	
Substance Abuse				**<0.001**
Smoking: Yes No	4 053 (17.5) 19 073 (82.3)	245 (6.0) 602 (3.2)	3 808 (94.0) 18 471 (96.8)	
Not Stated	58 (0.2)	3	55	
Diseases				
Diabetes: Yes No	848 (3.7) 21 849 (94.2)	32 (3.8) 796 (3.6)	816 (96.2) 21 053 (96.4)	0.840
Not Stated	487 (2.1)	22	465	
HIV: Yes No	696 (3.0) 21 521 (92.8)	134 (19.2) 662 (3.1)	562 (80.8) 20 859(96.9)	**<0.001**
Not Stated	967 (4.2)	54	913	
Personal Income				
0 - 900	923 (4.0)	56 (6.1)	867 (93.9)	**0.001**
901 – 2000	1 191 (5.1)	49 (4.1)	1,142 (95.9)	
2001 -3500	1 929 (8.3)	93 (4.8)	1,836 (95.2)	
3501 -7500	1 701 (7.3)	61 (3.5)	1,640 (96.5)	
7501 14 500	971 (4.2)	24 (2.5)	947 (97.5)	
14501 – 20 000	432 (1.9)	4 (0.9)	428 (99.1)	
>20 001	381 (1.6)	7 (1.8)	374 (98.2)	
Not Stated	15 590 (67.2)	556	15,034	
Received 13th cheque or bonus				0.809
Yes	2 141 (9.2)	76 (3.6)	2 065 (96.4)	

No	4 575 (19.7)	163 (3.6)	4 412 (96.4)	
Not Stated	16 468 (71.1)	611(3.7)	15 857 (96.3)	
Medical aid				**0.074**
Yes	1 232 (5.3)	30 (2.4)	1 202 (97.6)	
No	5 493 (23.7)	208 (3.8)	5 285 (96.2)	
Not Stated	16 459 (71.0)	612 (3.7)	15 847 (96.3)	

* Chi^2 (X^2) test for binary/ categorical variables

3.1.1. Distribution of TB cases among explanatory variables

The distribution of TB among workers in South Africa (Table 1) revealed that, despite the predominance of women in the survey, men had a significantly increased proportion of reported TB ($p<0.001$). Participants aged between 41 and 60 years had a higher proportion of reporting TB than participants aged 25 years and below ($p <0.001$). A higher proportion of participants who were of the Coloured ethnic group reported TB compared to Africans, Whites, and the Indian ethnic group ($p<0.001$). Additionally, there was a greater proportion of participants who were married or living with a partner who had high rates of reported TB compared to participants who were not married ($p<0.001$). Despite the predominance of participants with secondary education in the survey, those who reported having primary education had an increased percentage of reported TB as compared to those who had no form of education, secondary education, or post-matric education ($p<0.001$). Tuberculosis proportions differed significantly across different provinces, with participants residing in the Eastern Cape having a higher prevalence of reported TB compared to those in other provinces ($p < 0.001$).

3.1.2. Employment Status, Household Income, occupation group, and Sector for the employed

Table 1 showed that employment status played a role, with reported TB proportions significantly higher among those who were sick or living with a disability (n = 81, 11.5%,

$p < 0.001$) and among individuals who were casual workers ($n = 70$, 7.0%, $p < 0.001$). Despite the predominance of elementary occupations in the survey, those who worked in the armed forces also had a significantly higher proportion of reported TB ($n = 1$, 10.0%, $p < 0.001$). Participants who worked in sectors such as agriculture, hunting, forestry, and fishing had increased reported TB proportions compared to other sectors (n=42, 5.6%, $p = 0.002$), followed by those in construction ($p = 0.002$). The results revealed that households with an income much below the average had a higher prevalence of TB (n=193, 5.4%, $p < 0.001$), followed by those who earned below average income (n=234, 4.2%, $p < 0.001$). The lowest percentage of reported TB was in the participants who earned above average income (n=45, 2.3%, $p < 0.001$).

3.1.3. Risk factors for TB: BMI, HIV, Smoking, and Diabetes

Table 1 showed that the proportions of reporting having TB were significantly higher among underweight participants ($n = 135$, 7.8%, $p < 0.001$), followed by those of normal weight ($n = 424$, 4.5%, $p < 0.001$). The lowest proportions of reported TB were in individuals with obese BMI (n=130, 2.1%, $p < 0.001$). A significant increase in the proportions of those who had reported TB was in those who smoked (n=245, 6.0%, $p < 0.001$), despite the majority being non-smokers. Participants who were diagnosed with diabetes (n=38, 3.8%) reported a non-significantly higher proportion of reported TB compared to those who did not report TB ($p = 0.809$). Despite the large number of participants falling into those who did not have HIV, those who had HIV had a significantly increased proportion of reported TB (n=134, 19.2% $p < 0.001$) as compared to those who did not have HIV.

TB prevalence by mean monthly personal income with 13th cheque and medical aid for participants who worked for pay.

Personal income was reported for the subgroups who indicated being employed, self-employed, and casual workers (Table 1). Participants whose personal income was R900 and below had a higher proportion of reported TB (n= 56, 6.1%) compared to those who earned above R900, followed by those who earned between R2,001 and R3,500 (n=93, 4.8%). Receiving the 13th cheque or bonus was not associated with reported TB (p =

0.809). Having access to medical aid was not significantly associated with reported TB ($p = 0.074$), with those who did not have access to medical aid having a higher proportion of reported TB ($n = 208$, 3.8%). However, there was a significant association between personal income and reported TB. Although personal income showed a significant association with reported TB ($p<0.001$), the large number of missing participants suggested that household income group was a better indicator for the odds of reported TB compared to personal income.

Map of tuberculosis (TB) distribution in South Africa, categorized by occupation.

Tuberculosis rates, calculated from the number of reported cases and the study population of each province, were plotted by province using different shades of orange, which demonstrate the varied prevalence of reported TB by province. The highest proportion of reported tuberculosis was observed in the Eastern Cape (6.4%), followed by the North West (5.3%), while Limpopo had the lowest rate of reported TB.

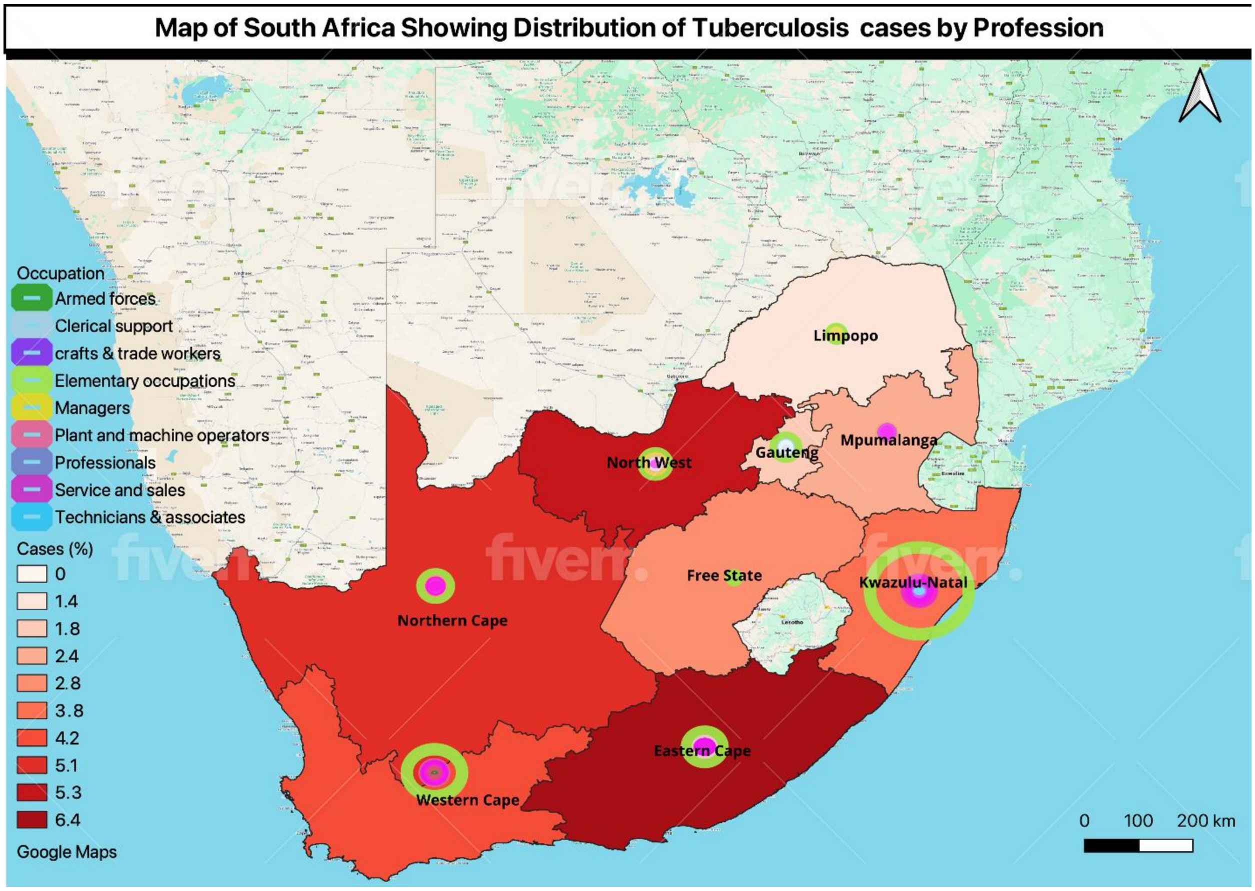


Figure 1: Map of South Africa showing the distribution of TB Proportions by Province and Occupation

The map in Figure 1 features colored circles in each province, which were used to visualize the impact of tuberculosis on different occupational groups in each province in South Africa in 2017. The map illustrates the distribution of reported tuberculosis (TB) cases across South African provinces, stratified by predominant occupations, highlighting the occupation group most affected in each province. Occupational groups were classified according to the South African Standard Classification of Occupations (SASCO), with only the occupation group most affected in each province shown. The size of the circle represents the proportion of reported TB, while the color represents the occupation group.

Tuberculosis proportion is highest in the Eastern Cape, Northern Cape, and KwaZulu-Natal, with case percentages ranging from 5.1% to 6.4%. Lower proportions are observed in Limpopo and Gauteng (≤1.8%). Occupational patterns indicate that TB cases are concentrated among service and sales workers, elementary occupations, and clerical support in the high-burden provinces. Conversely, provinces with lower reported TB burden exhibit fewer cases across all occupational categories. These findings highlight a combined spatial and occupational disparity in TB distribution, suggesting that interventions should target high-risk regions and occupational groups to reduce TB transmission effectively.

Occupation groups and reported TB were adjusted for demographic and other risk factors.

The role of occupation in TB in South Africa was indicated in this study by determining the odds of reported TB by occupation group after adjusting for known risk factors, effect modifiers, and confounders.

Table 2: Crude and adjusted odds ratios for occupation group and factors associated with TB among workers in NIDS wave 5 (N=23,184)

TB	cOR n=23184	95% CI	p-value	aOR n = 5235	95% CI	P-value
Age Category						
15 – 25	**Ref**					
26 – 30	2.0	1.4 – 2.7	**0.000**	1.9	1.0 – 3.8	**0.051**
31 – 35	3.2	2.4 – 4.2	**0.000**	3.2	1.7 – 6.1	**0.000**
36 – 40	4.0	3.0 – 5.4	**0.000**	4.9	2.5 – 9.4	**0.000**
41 – 45	5.8	4.5 – 7.7	**0.000**	5.8	3.0 – 11.3	**0.000**
46 – 50	5.2	4.0 – 7.0	**0.000**	5.8	2.9 – 11.9	**0.000**
51 – 55	3.7	2.7 – 5.1	**0.000**	3.1	1.4 – 7.1	**0.006**
56 – 60	4.8	3.6 – 6.5	**0.000**	5.3	2.2 – 12.4	**0.000**

61 – 65	4.0	2.9 – 5.6	**0.000**	1.8	0.2 – 14.8	0.568
66 – 70	3.2	2.2 – 4.8	**0.000**	9.6	1.8 – 50.1	**0.007**
71 – 75	2.4	1.4 – 4.1	**0.001**	1.9	1.0 – 3.8	**0.051**
Race						
Asian/Indian	**Ref**					
African	4.7	1.5 – 14.8	**0.007**	**-**	**-**	**-**
Coloured	7.2	2.3 – 22.8	**0.007**	**-**	**-**	**-**
White	0.8	0.2 – 2.9	0.679	-	-	-
Marital Status						
Not Married	**Ref**					
Married or living with a partner	1.3	1.1 – 1.5	**0.003**	0.8	0.6 – 1.2	0.317
Province of Residence						
Gauteng	**Ref**					
Western Cape	1.5	0.7 – 2.8	0.269	2.3	1.2 – 4.2	**0.010**
Eastern Cape	3.2	1.9 – 5.4	**0.000**	3.9	2.0 – 7.3	**0.000**
Northern Cape	2.9	1.5 – 5.6	**0.001**	2.1	1.0 – 4.1	**0.036**
Free State	1.5	0. – 2.3	0.249	0.3	0.1 – 1.5	0.159
KwaZulu-Natal	2.1	1.6 – 2.8	**0.000**	2.4	1.4 – 4.3	**0.002**
North West	3.0	2.1 – 4.2	**0.000**	2.6	1.3 – 5.4	**0.009**
Mpumalanga	1.3	0.9 – 1.9	0.208	1.4	0.6 – 3.1	0.446
Limpopo	0.7	0.5 – 1.2	0.193	0.7	0.3 – 2.1	0.571
Employment Status						
Home Maker or Childcare	**Ref**					

Employed	1.2	0.9 – 1.6	0.265	-	-	-
Unemployed	1.4	1.0 – 1.9	**0.048**	**-**	**-**	**-**
Self-employed	1.1	0.7 – 1.7	0.574	-	-	-
Casual work	2.4	1.7 – 3.6	**0.000**	**-**	**-**	**-**
Subsistence farming	1.3	0.6 – 3.1	0.545	-	-	-
Assist in business	1.7	0.6 – 4.8	0.328	-	-	-
Retired or over 65 years of age	1.4	1.0 – 2.0	**0.031**	-	-	-
Student	0.3	0.2 – 0.5	**0.000**	-	-	-
Sick or living with disability	4.2	2.9 – 6.1	**0.000**	**-**	**-**	**-**
Pregnant	1.0	0.4 – 2.9	0.956	**-**	**-**	**-**
Occupation for the employed.						
Professionals	**Ref**					
Agriculture, Forestry, Fishery laborers	2.0	0.2 – 17.3	0.541	1.1	0.1 – 9.1	0.959
Armed forces	8.3	0.9 – 78.6	0.065	-	**-**	**-**
Clerical Support	1.4	0.4 – 4.7	0.558	2.0	0.7 – 5.9	0.217
Crafts and Trade Workers	2.8	1.1 – 7.5	**0.035**	2.2	1.0 – 5.1	0.062
Elementary Occupations	4.5	1.8 – 11.1	**0.001**	3.2	1.5 – 6.8	**0.002**
Managers	1.5	0.4 – 4.9	0.530	1.1	0.3 – 3.6	0.918
Plant and Machine Operators	4.9	1.9 – 12.6	**0.001**	3.7	1.7 – 8.3	**0.001**
Service and Sales	1.8	0.7 – 4.7	0.245	1.5	0.7 – 3.6	0.305
Technicians and Associates	-	-	**-**	1.2	0.4 – 3.6	0.795
Household Income						
Much Above Average Income	**Ref**					

Much Below Average Income	2.2	1.4 – 3.6	**0.002**	3.9	1.2 –13.0	**0.029**
Below Average Income	1.7	1.0 – 2.8	**0.034**	3.5	1.1 –11.5	**0.041**
Average Income	1.3	0.8 – 2.1	0.304	2.9	0.9 – 9.5	0.073
Above Average Income	0.9	0.5 – 1.6	0.733	2.5	0.7 – 8.8	0.164
BMI Category						
Underweight	**Ref**					
Normal weight	0.6	0.5 – 0.7	**0.000**	0.5	0.3 – 0.9	**0.014**
Overweight	0.3	0.3 – 0.4	**0.000**	0.3	0.2 – 0.6	**0.000**
Obese	0.3	0.2 – 0.3	**0.000**	0.1	0.1 – 0.3	**0.000**
Smoking						
No	**Ref**					
Yes	2.0	1.6 – 2.3	**0.000**	1.3	0.9 – 1.8	0.195
Diabetes						
No	**Ref**					
Yes	1.0	0.7 – 1.5	0.842	-	-	-
HIV						
No	**Ref**					
Yes	7.5	6.1 – 9.2	**0.000**	2.8	1.7 – 4.9	**0.000**

*COR = Crude Odds Ratio, AOR = Adjusted Odds Ratio, CI = Confidence Interval, *Statistically significant p-value < 0.05*

The factors associated with reported TB among workers in the bivariate analyses (cOR) were age, race, marital status, province, employment status, occupation, household income, BMI, smoking, and HIV. The bivariate analysis showed that age had an increased odds of reported TB as the age group increased (p=0.001). Under employment status, the odds of reported TB among participants who were casual workers, unemployed, retired, and sick, or living with disability were significantly higher than the odds of reported TB among participants who were homemakers or doing child care (p<0.001).

Crude Association with Reported TB

The crude analysis (Table 2) showed that the risk of reporting TB increased significantly with age, particularly among individuals aged 31–75 years compared to those aged 15–25 years. The odds of TB were exceptionally high in the 41–45 age group (cOR = 5.8, 95% CI: 4.5–7.7, p<0.001). By race, Coloured participants (cOR = 7.2, 95% CI: 2.3–22.8, p=0.007) had higher odds of reported TB compared to Asian/Indian participants. Provincially, Eastern Cape (cOR = 3.2, 95% CI: 1.9–5.4, p<0.001), Northern Cape (cOR = 2.9, 95% CI: 1.5–5.6, p=0.001), KwaZulu-Natal (cOR = 2.1, 95% CI: 1.6–2.8, p<0.001), and North West (cOR = 3.0, 95% CI: 2.1–4.2, p) all demonstrated higher odds of reported TB compared to Gauteng.

Employment status showed that those engaged in casual work (cOR = 2.4, 95% CI: 1.7–3.6, p<0.001), the unemployed (cOR = 1.4, 95% CI: 1.0–1.9, p=0.048), the retired (cOR = 1.4, 95% CI: 1.0–2.0, p=0.031), and especially individuals who were sick or living with a disability (cOR = 4.2, 95% CI: 2.9–6.1, p<0.001) had increased odds of reported TB compared to homemakers. Conversely, students had significantly lower odds of TB (cOR = 0.3, 95% CI: 0.2–0.5, p<0.001). Occupational analysis revealed elevated odds of reported TB among crafts and trade workers (cOR = 2.8, 95% CI: 1.1–7.5, p=0.035), elementary workers (cOR = 4.5, 95% CI: 1.8–11.1, p=0.001), and plant and machine operators (cOR = 4.9, 95% CI: 1.9–12.6, p=0.001) compared to professionals. Socio-economic and health factors were also significant. Participants from much-below-average income households (cOR = 2.2, 95% CI: 1.4–3.6) and below-average households (cOR = 1.7, 95% CI: 1.0–2.8) were at higher risk of reported TB compared to those from above-average income households. The odds of reported TB among participants whose BMI was categorized into being overweight (cOR= 0.3, 95% CI: 0.3 – 0.4, p<0.001) and obese (cOR= 0.3, 95% CI: 0.2 – 0.3, p<0.001) were 70% less compared to participants whose BMI was categorized into being underweight. Participants who smoked had 2 times higher odds of reported TB compared to those who were not smokers (cOR=2.0, 95% CI: 1.6 –

2.3, p<0.001). Additionally, the odds of reported TB among participants who reported having HIV/AIDS (cOR = 7.5, 95% CI: 6.1–9.2, P<0.001) were nearly 8 times higher compared to those who did not report having HIV/AIDS.

In some categories, the number of TB cases was fewer than five, resulting in unstable estimates with wide confidence intervals. For example, participants in the armed forces had markedly higher odds of TB (cOR = 8.3, 95% CI: 0.9–78.6, p = 0.065), and those in agriculture, forestry, and fishery occupations also showed increased odds (cOR = 2.0, 95% CI: 0.2–17.3, p = 0.541). However, due to the small sample sizes, the estimates are unstable and may not provide reliable evidence of association.

Adjusted Association with Reported TB

In the adjusted logistic regression analyses, many variables remained significant independent factors associated with TB. Diabetes, smoking, marital status, and race were not important factors in this dataset. Elementary workers and plant and machine operators had significantly higher odds of reporting TB out of the occupation groups, independent of HIV status, BMI, and income. Craft and trade workers showed an increased odds ratio for reported TB, although this was only close to significant in this data.

The odds of reported TB among participants aged 66–70 years (aOR = 9.6, 95% CI: 1.8–50.1, p=0.007) were nearly 10 times higher compared to participants aged 15–25 years, and this difference was statistically significant. The odds of those 41-50 years followed those of the 66–70-year-olds for the highest significant odds of reported TB. The province of residence was a significant factor, with participants residing in the Eastern Cape province having nearly 4 times statistically significant higher odds of reported TB compared to participants who resided in Gauteng province (aOR = 3.7, 95% CI: 2.0 – 7.3, p<0.001). Additionally, participants whose households earned much below average income had nearly 4 times higher odds of reported TB compared to participants who earned much above average income (aOR = 3.9, 95% CI: 1.2 – 13.0, p=0.029). The odds of reported TB among participants whose BMI was categorized into being obese (aOR = 0.1, 95% CI: 0.1 – 0.3, p<0.001) were 90% less compared to participants whose BMI was categorized into being underweight. Although participants who smoked had 30% times higher odds of reported TB compared to participants who were not smokers, it was not statistically significant (aOR = 1.3, 95% CI: 0.9 – 1.8, p=0.195). The odds of reported TB among participants who were diagnosed with HIV/AIDS (aOR = 2.8, 95% CI: 1.7 – 4.9, p<0.001) were nearly 3 times higher compared to those who were not diagnosed with HIV/AIDS, and statistically significant.

The logistic regression model assessing the association between occupation for employed and tuberculosis (TB), while adjusting for demographic and other factors, demonstrated a reasonable fit to the data. Furthermore, the goodness-of-fit test produced a p-value of 0.5528, indicating that the model adequately fits the data. A p-value above 0.05 suggests that the model is appropriate for explaining the relationship between occupation and TB (Appendix III).

CHAPTER 4 – DISCUSSION

4. Chapter Outline

This chapter presents the discussion of results in the following order: description of demographic factors and their association with tuberculosis, mapping of reported TB among different occupations according to SASCO groups, and factors associated with tuberculosis among workers in South Africa using the NIDS.

4.1. Demographic factors

This study explored the sociodemographic, occupational, and other factors associated with reported TB among South African workers. The findings highlight disparities in reported TB prevalence linked to age, ethnicity, geography, employment conditions, and health status, aligning with and expanding upon existing literature on reported TB epidemiology.

A large proportion of participants were aged 15–25 years, predominantly from the Black ethnic group, unmarried, and unemployed. However, TB proportion increased with age, peaking at 41–45 years in this study. This differs from WHO (2023) estimates, which highlight the highest global TB burden among adults aged 25–54 years, and from research in South-East Asia and the Western Pacific, where the burden is concentrated among those 65 years and older (Caraux-Paz *et al*., 2021). These differences may reflect regional variations in age structure, HIV co-infection, and occupational exposure. The increased prevalence in older age groups in our study is consistent with biological evidence that aging is associated with declining lung function and immune capacity, which increases susceptibility to TB infection (Lowery *et al*., 2013).

Ethnicity emerged as an important factor, with the Coloured group reporting the highest TB prevalence and the White group the lowest. This aligns with evidence from Chimusa *et al*. (2014), which highlighted how socio-economic inequalities, historical disadvantage, and differential access to healthcare contribute to racial disparities in TB burden in South Africa. Interestingly, while marital status appeared significant in descriptive analysis, this association did not persist after adjustment. Our findings, therefore, differ from Dhlakama *et al*. (2022) and Lienhardt *et al*. (2005), who reported that unmarried adults—particularly men—had a higher risk of TB. These inconsistencies may reflect contextual differences, such as socioeconomic status or gender norms that influence exposure, health-seeking, and reporting, suggesting that marital status may act as a proxy for other social determinants rather than a direct risk factor.

Geographical differences in TB proportions were observed, with the Eastern Cape showing the highest burden. This finding is consistent with Churchyard *et al*. (2014), who highlighted how entrenched poverty, limited healthcare access, and historical mining exposures contribute to the province's elevated TB rates. The increased prevalence among participants who were sick, living with disability, or engaged in casual work further underscores the role of social and occupational disadvantage in shaping TB risk. These associations are in line with Erlinger *et al*. (2019), who showed that poor living conditions and restricted access to healthcare increase vulnerability to TB. Together, these findings suggest that provincial disparities may not only reflect differences in TB transmission dynamics but also structural inequalities that limit access to stable employment, social protection, and timely healthcare.

Although most participants had a normal BMI, underweight individuals were more likely to report TB, reinforcing evidence that malnutrition weakens immune defenses and increases susceptibility (WHO, 2021). Smoking did not emerge as a significant factor in this study, likely due to the minimal number of smokers reported. However, the slight increase in odds aligns with established evidence that smoking elevates TB risk (Smith *et al*., 2015). The lack of statistical significance may be explained by underreporting, a form of social desirability bias observed in other studies (Althubaiti, 2016).

Socioeconomic disadvantage also played a clear role. Participants from households with 'much below average' income bore the most significant TB burden, consistent with global evidence that poverty amplifies risk through delayed health-seeking, overcrowding, inadequate nutrition, and limited healthcare access (Lönnroth *et al*., 2010; Chimusa *et al*., 2014). While Chimusa *et al*. (2014) primarily examined genetic predisposition, they underscored how structural inequalities shape TB vulnerability, echoing the findings in this study. Collectively, these results highlight the interconnected role of malnutrition, behavioral risks, and poverty in sustaining the TB epidemic in South Africa.

4.2. Map of distribution of Tuberculosis rates by occupations in South Africa

Provincial differences in TB proportions were evident, with the Eastern Cape showing the highest burden, followed by the North West. This aligns with recent evidence that TB prevalence among adults is disproportionately high in the Eastern Cape, a province long affected by poverty, mining-related exposures, and limited healthcare access (Okokuwebe *et al*., 2024). Occupational variation further highlighted structural vulnerabilities: elementary workers consistently showed the highest TB proportions in most provinces, particularly in KwaZulu-Natal and the Western Cape, reflecting evidence that precarious, low-skilled work often involves crowded conditions, silica exposure, and poor access to occupational health services (Kootbodien *et al*., 2018; Mlangeni *et al*., 2023). By contrast, the armed forces in the Western Cape reported the lowest TB prevalence, possibly reflecting better healthcare access, systematic screening, and job-related protections.

The exception observed in the Free State, where elementary workers had the lowest reported TB, suggests potential underdiagnosis, reporting bias, or regional differences in occupational health coverage. Such inconsistencies highlight the need for more standardized surveillance across provinces. Mapping these occupational patterns is therefore valuable, as it reveals both expected and unexpected hotspots, enabling policymakers to design targeted interventions that address these areas effectively. Workplace-specific TB prevention strategies, including occupational health programs and subsidized treatment, may be particularly effective in reducing TB risk among vulnerable worker groups (Lan and Delmelle, 2023).

4.3. Factors associated with TB among workers in South Africa in multivariable analysis.

Multivariable analysis indicated that participants aged 66–70 years had the highest odds of reported TB compared to those aged 25 years and below. This aligns with evidence that older adults are more vulnerable to TB due to age-related immune decline and the cumulative risk of exposure over a lifetime (Byng-Maddick and Noursadeghi, 2016).

Residing in the Eastern Cape was also associated with increased TB risk, consistent with prior reports highlighting the province's persistently high TB prevalence, likely driven by poverty, historical mining exposures, and limited healthcare access (Okokuwebe *et al*., 2024). Structural factors further contribute to regional vulnerability: high HIV prevalence in KwaZulu-Natal and labor migration to mining areas in the North West increase TB susceptibility through overlapping epidemics, population mobility, and economic disadvantage. Studies indicate that migrants often face barriers to HIV and TB services due to stigma and documentation issues, exacerbating infection risk for both miners and their communities (Shisana *et al*., 2014; Vearey, 2011).

Body Mass Index was significantly associated with TB risk, with overweight and obese participants exhibiting lower odds of reported TB compared to underweight participants. This contrasts with a study in China, where obesity was linked to higher TB infection rates measured via QuantiFERON-TB Gold testing (Zhang *et al*., 2017). The protective effect of higher BMI in our study may reflect the role of nutritional reserves in supporting immune function. In contrast, regional differences in study populations and diagnostic methods could explain the contrasting findings.

The presence of an HIV infection markedly increased TB risk, with HIV-positive participants 2.8 times more likely to report TB than HIV-negative participants. This aligns with prior studies among South African agricultural and healthcare workers, which reported a 3.16 increased TB risk among people living with HIV (Mlangeni *et al*., 2023; Tudor, 2016) and corroborates WHO (2023) data indicating that HIV accounts for a substantial proportion of TB cases globally. In contrast, diabetes was not associated with TB in this dataset, despite evidence elsewhere suggesting a 1.5 times increased risk (WHO, 2021), potentially reflecting underdiagnosis or sample characteristics.

Occupational factors were strongly associated with TB risk. Plant and machine operators, followed by elementary workers, had higher odds of reported TB than professionals, consistent with prior evidence linking hazardous working conditions, silica exposure, and limited occupational healthcare access to increased TB burden (Kootbodien *et al*., 2018; Mlangeni *et al*., 2023). Similarly, participants in the lowest income brackets had elevated TB risk, supporting global evidence that poverty exacerbates TB susceptibility through overcrowding, limited healthcare access, and delayed care-seeking (Barter *et al*., 2012).

Among employed participants, plant and machine operators had the highest odds of reported TB compared to professionals, followed closely by workers in elementary occupations. This is consistent with evidence from Kootbodien *et al*. (2018), who reported elevated TB mortality among mining-sector plant and machine operators, and Mlangeni *et al*. (2023), who linked higher TB rates in low-skilled occupations to hazardous working conditions and limited access to healthcare. These findings suggest that occupational exposure, including dust, silica, and physically demanding work, combined with inadequate workplace health services, significantly increases TB risk.

Income further modulated TB risk, with participants earning much below average income exhibiting higher odds of reported TB than those earning above average. This aligns with Barter *et al*. (2012), who found that approximately 20% of the poorest income earners are at elevated risk for TB, likely due to factors such as overcrowded living conditions, malnutrition, and delayed healthcare seeking. Together, these results highlight the intersection of occupational and socioeconomic vulnerability in shaping TB risk, emphasizing the need for targeted workplace interventions and social protection policies to reduce TB among high-risk workers.

Strengths and Limitations

Strength

The main strength of this study lies in its large sample size and adequate power for statistical analysis. The data enabled us to generalize across all provinces since the NIDS dataset covered all provinces in South Africa. The NIDS study was a large nationally representative sample with reasonable quality control. The data contained a detailed investigation into employment status and income, thus allowing us to investigate occupation groups and TB.

Limitations

This study used secondary data, which limited the ability to control data quality. The participants' descriptive statistics, especially occupation for employed, were missing on some participants' questionnaires, and this affected the analysis of these variables (occupation for employed). The study's national coverage is a strength for describing overall TB trends; however, differing sample sizes across provinces reduced the precision and power of interprovincial comparisons, and provincial estimates should therefore be interpreted with caution. Potential bias may have arisen from changes in data storage systems over time, which could have affected data integrity and completeness through loss of records, inconsistent variable coding, or errors introduced during data migration. Additionally, the cross-sectional design of the survey limits the ability to infer causality between risk factors and TB. The reliance on self-reported TB status may also introduce reporting bias, including underreporting due to stigma or recall errors.

5. CONCLUSION

This study demonstrated significant associations between age, province, occupation, household income, BMI, and HIV status with reported TB among workers in South Africa. Notably, participants aged 66–70 years and those residing in the Eastern Cape province had a higher risk of TB. Increased risk was also observed among plant and machine operators, individuals who were sick or living with a disability, and those living with HIV. Tuberculosis illness may lead to increased absenteeism and reduced productivity, highlighting the broader implications for workplace health. These findings contribute to the literature by identifying high-risk worker populations and geographic areas, providing evidence to inform targeted public health interventions and occupational health policies aimed at reducing TB burden among vulnerable groups. Moreover, the study contributes to the literature by providing evidence on occupational and sociodemographic determinants of TB in South Africa, which can guide future research and public health interventions.

6. RECOMMENDATIONS

Reducing tuberculosis (TB) in workplaces can lower treatment costs for both individuals and the healthcare system. It will also support progress toward the global target of ending TB by 2035 and help meet international obligations. At the workplace level, reducing TB can lead to decreased absenteeism, improved productivity, and reduced staff turnover. The Department of Health, companies, and managers should ensure that existing workplace policies on TB and HIV/AIDS are not only in place but also actively enforced. This can be achieved by monitoring compliance, providing regular employee training, integrating TB screening into occupational health programs, and ensuring that workers have access to care without discrimination. Providing support to employees through awareness campaigns and promoting regular medical check-ups at the workplace can benefit workers who do not routinely visit health facilities, without disrupting service delivery or productivity.

Stigma related to TB should be addressed directly. Workplace workshops, health campaigns, and educational talks can help dispel myths, increase understanding of TB transmission and treatment, and encourage individuals to undergo testing. Reducing stigma will create a safer environment for disclosure and treatment, and employees can extend this knowledge to their families and communities. Finally, to effectively address the burden of TB, it is essential to understand how its prevalence differs across occupational groups, since TB remains a primary occupational health concern.

REFERENCES

Akokuwebe ME, Osuafor GN, Idemudia ES. (2024). Prevalence and association of HIV and tuberculosis status in older adults in South Africa: an urgent need to escalate the scientific and political attention to aging and health. *Front. Public Health*, 12:1245553.

Alavi-Naini R, Sharifi-Mood B, Metanat M. (2012). Association Between Tuberculosis and Smoking. *Int J High Risk Behav Addict*, 1(2):71–74.

Alisjahbana B, Sahiratmadja E, Nelwan EJ, *et al*. (2007). The effect of type 2 diabetes mellitus on the presentation and treatment response of pulmonary tuberculosis. *Clinical Infectious Diseases*, 45(4):428–435.

Althubaiti A. (2016). Information bias in health research: definition, pitfalls, and adjustment methods. J Multidiscip Healthc, 9: 211 – 7. Amere GA, Nayak P, Salindri AD., *et al*. 2018. Contribution of smoking to tuberculosis incidence and mortality in high-tuberculosis-burden countries. *AM J Epidemiol*, 187(9): 1846 – 1855.

Barter DM, Agboola SO, Murray MB., *et al*. 2012. Tuberculosis and poverty: the contribution of patient costs in sub-Saharan Africa – a systematic review. *BMC Public Health*, 12:980. https://doi.org/10.1186/1471-2458-12-980.

Benatar SR. 2013. The challenges of health disparities in South Africa. *S.Afr.Med*, 103: 154-155.

Bhargava A. 2016. Undernutrition nutritionally acquired immunodeficiency, and tuberculosis control. *BMJ,* 355: i5407.

Byng-Maddick R, Noursadeghi M. 2016. Does tuberculosis threaten our ageing populations? *BMC Infect Diseases*, 16: 3-5.

Caraux-Paz P, Diamantis S, de Wazières B., *et al.* 2021. Tuberculosis in the Elderly. *J. Clin. Med*, 10: 5888.

Carter BB, Zhang Y, Zhao H., *et al*. 2021. Survival analysis of patients with tuberculosis and risk factors for multidrug-resistant tuberculosis in Monrovia, Liberia, 16(4): e0249474.

Carwile ME, Hochberg NS, Sinha P. 2022. Undernutrition is feeding the tuberculosis pandemic: A perspective. *J Clin Tuberc Other Mycobact Dis,* 27:100311.

Chimusa ER, Zaitlen N, Daya M., *et al*. 2014. Genome-wide association study of ancestry-specific TB risk in the South African Coloured population. *Hum Mol Genet*, 23(3):796-809.

Daniels RC, Ingle KP, Brophy TSL. 2022. Determinants of attrition between Waves 1 and 2 of South Africa's National Income Dynamics Study – Coronavirus Rapid Mobile Survey (NIDS-CRAM). *South African Journal of Economics*, 90(4):535–52.

Davidson JA, Lalor MK, Anderson LF., *et al*. 2017. TB in healthcare workers in the UK: A cohort analysis 2009–2013. *Thorax*, 72(7):654–659.

Dias M, Gaio R, Sousa P., *et al*. 2017. Tuberculosis among the homeless: Should we change the strategy? *Int J of Tuberc and Lung Dis*, 21(3):327–332.

Ehrlich R, Akugizibwe P, Siegfried N., *et al*. 2021.The association between silica exposure, silicosis and tuberculosis: a systematic review and meta-analysis. *BMC Public Health*, 21(1):953.

Erlinger S, Stracker N, Hanrahan C., *et al*. 2019. Tuberculosis patients with higher levels of poverty face equal or greater costs of illness. *Int J Tuberc Lung Dis,* 23(11):1205-1212.

Feldman C, Theron AJ, Cholo MC., *et al*. 2024. Cigarette Smoking as a Risk Factor for Tuberculosis in Adults. Epidemiology and Aspects of Disease Pathogenesis, Pathogens, 13:151.

Feleke BE, Feleke TE, Biadglegne F. 2019. Nutritional status of tuberculosis patients, a comparative cross-sectional study. *BMC pulm med*, 19:182. Available from: https://doi.org/10.1186/s12890-019-0953-0. [Accessed 11 March 2024].

Garfein RS, Burgos JL, Rodriquez-Lainz A., *et al*. 2011. Latent tuberculosis infection in a migrant agricultural community in Baja California, Mexico. *J Immigr Minor Health*, 13(5):940–7.

Glaziou P, Floyd K, Raviglione MC. 2018. Global Epidemiology of Tuberculosis. *Semin Respir Crit Care Med,* 39(3): 271 – 285.

Grobler L, Mehtar S, Dheda K., *et al*. 2016. The epidemiology of tuberculosis in health care workers in South Africa: A systematic review. *BMC Health Serv Res*, 16(1): 174-177.

Gupta KB, Gupta R, Atreja A., et al. 2009. Tuberculosis and nutrition. *Lung India*, 26: 9-16.
Hnizdo E, Murray J. 1998. Risk of pulmonary tuberculosis relative to silicosis and exposure to silica dust in South African gold miners. *Occup Environ Med*, 55(7):496-502.

Holmes KK, Bertozzi S, Bloom BR., *et al*. 2017. Major Infectious Diseases: Key Messages from Disease Control Priorities, Third Edition.

Human Sciences Research Council. 2022. TB Prevalence in South Africa. Available:https://hsrc.ac.za/uploads/pageContent/1046956/TB%20Prevalence%20S urvey%20SA_2022_SML%20(003)-%20march%202002%20. [Accessed 09 September 2024].

Human Sciences Research Council. 2023. The sixth South African National HIV Prevalence, Incidence, and Behaviour Survey (SABSSM VI). Available: https://sahivsoc.org/Files/SABSSM-FINAL-LAUNCH-presentation-27November2023-1.pdf [Accessed 24 July 2024].

Kalichma SC, Katner H, Banas E., *et al*. 2020. Cumulative effects of stigma experiences on retention in HIV care among men and women in the rural Southeastern United States. AIDS Patient Care and STDs, 34(11): 484-490.

Kier KL. 2011. Biostatistical applications in epidemiology. Pharmacotherapy, 31(1): 9-22.

Knight GM, Dodd PJ, Grant AD., et al. 2015. Tuberculosis prevention in South Africa, 10:4.

Koch A, Mizrahi V. 2018. Mycobacterium tuberculosis. *Trends Microbiol*, 26(6): 555–556.

Kootbodien T, Iyaloo S, Wilson K., *et al*. 2019. Environmental silica dust exposure and pulmonary tuberculosis in Johannesburg, South Africa. *Int J Environ Res Public Health*, 16(10):1867.

Kootbodien T, Wilson K, Tlotleng N., *et al*. 2018. Tuberculosis mortality by occupation in South Africa, 2011–2015. *Int J Environ Res Public Health*, 15(12): 2756.

Kumar Nathella P, Babu S. 2017. Influence of diabetes mellitus on immunity to human tuberculosis. *Immunology*, 152(1)13–24.

Kyu HH, Maddison ER, Henry NJ., *et al*. 2018. The global burden of tuberculosis: results from the Global Burden of Disease Study 2015. *Lancet Infect Dis*, 18(3):261–84.

Lam D, Leibbrandt M, Mlatsheni C. 2009. Education, and youth unemployment in South Africa. Labor Markets and Economic Development. Cape Town: University of Cape Town.

Lan Y, Delmelle E. Space-time cluster detention techniques for infectious diseases: A systematic review. Spatial and spatio-temporal epidemiology. 2023; 44: 100563.

Lappeman J, Egan P, Rightford G., *et al*. 2021. *Marketing to South African Consumers*, 1(1): 69-86. Available: https://doi.org/10.15641/0-7992-2548-8. [Accessed 13 May 2023]

Lienhardt C, Fielding K, Sillah JS., *et al*. 2005. Investigation of the risk factors for tuberculosis: a case-control study in three countries in West Africa. *Int J Epidemiol*, 34:914–23.

Lönnroth K, Castro KG, Chakaya JM., *et al*. 2010. Tuberculosis control and elimination 2010 – 50: cure, care, and social development. *Lancet*, 375(9728): 1814 – 1829.

Lowery EM, Brubaker AL, Kuhlmann E., *et al*. 2013. The aging lung. *Clin. Interv*, 8: 1489 – 1496.

Lönnroth K, Williams BG, Standlin S, Jaramillo E, Dye C. 2008. Alcohol use as a risk factor for tuberculosis- a systematic review. *BMC Public Health*, 8(1):287-289.

Maher D, Harries A, Getahun H. 2005. Tuberculosis and HIV interaction in sub-Saharan Africa: Impact on patients and programmes; implications for policies. *Tropical Medicine and International Health*, 10(8):734–42.

Malangu N, Legothoane A. 2013. Analysis of occupational infections among health care workers in Limpopo province of South Africa. *Glob J Health Sci*, 5(1):44–51.

Maleta K. 2006. Undernutrition. *Malawi Med J*, 18(4): 189-205.

Mlangeni N, Malotle M, Made F., *et al*. 2023. Factors associated with TB screening among agricultural workers in Limpopo Province, South Africa. *Glob Health Action*, 16(1):2162227.

Myers B, Bouton TC, Ragan EJ., *et al*. 2018. Impact of alcohol consumption on tuberculosis treatment outcomes: A prospective longitudinal cohort study protocol. *BMC Infect Dis*, 18(1):488.

Narasimhan P, Wood J, Macintyre CR., *et al*. 2013. Risk factors for tuberculosis. *Pulmonary Medicine,* 2013: 1-11.

O'Hara LM, Yassi A, Bryce EA., *et al*. 2017. Infection control and tuberculosis in health care workers: An assessment of 28 hospitals in South Africa. *Int J of Tuberc and Lung Dis*, 21(3):320–326.

Oxlade O, Murray M. 2012. Tuberculosis and Poverty: Why Are the Poor at Greater Risk in India?,7(11): e47533.

Pedrazzoli D, Boccia D, Dodd PJ., *et al*. 2017. Modelling the social and structural determinants of tuberculosis: Opportunities and challenges. *Int J of Tuberc and Lung Dis*, 21(9): 957–964.

Pillay Y, Mvusi L, Mametja LD., *et al*. 2021. What did we learn from South Africa's first-ever tuberculosis prevalence survey? *South African Medical Journal*, 111(5): 402-404.

Ramaliba TM, Tshitangano TG, Akinsola HA., *et al*. 2017. Tuberculosis risk factors in Lephalale local municipality of Limpopo province, South Africa. *South Afr Fam Pract*, 59:182-187.

Rees D, Murray J. 2007. Silica, silicosis and tuberculosis. *Int J of Tuberc and Lung Dis*, 11(5):474-484.

Reid A, Grant AD, White RG., *et al*. 2015. Accelerating progress towards tuberculosis elimination: the need for combination treatment and prevention. *Int J of Tuberc and Lung Dis*, 19(1):5-9.
Rehm J, Samokhvalov AV, Neuman MG, Room*., et al*. 2009. The association between alcohol use, alcohol disorders and tuberculosis (TB). *Addiction*, 104(1): 118-128.

Rosenman KD, Hall N. 1996. Occupational risk factors for developing tuberculosis. *Am J Ind Med*, 30(2):148-154.

Sahile AT, Ayehu SM, Fanta SF. 2020. Undernutrition and its predictors among people living with HIV/AIDS attending antiretroviral therapy clinic in Jimma University Specialized Hospital. *Int J Nutri Metab*, 9(8):67-74.

Shimeles E, Enquselassie F, Aseffa A., *et al*. 2019. Risk factors for tuberculosis: A case-control study in Addis Ababa, Ethiopia, 14(4): e0214235.

Shisana O, Rehle T, Simbayi L., et al. 2014. *South African National HIV Prevalence, Incidence and Behaviour Survey, 2012*, Cape Town, HSRC Press. Available: https://hsrc.ac.za/uploads/pageContent/4565/SABSSM%20IV%20LEO%20final.pdf. [Accessed: 26 March 2025]

Smith GS, Van Den Eeden SK, Baxter R., *et al*. 2015. Cigarette smoking and pulmonary tuberculosis in northern California. *J Epidemiol Community Health*, 69(6):568-573.

South African Standard Classification of Occupations (SASCO). 2012. Available from: www.statssa.gov.za Accessed [03 February 2023]

StataCorp. 2023. Stata Statistical Software: Release 18. College Station, TX: StataCorp LLC. Available: https://www.stata.com/ [Accessed 23 June 2023]

The Sustainable Development Goals Report. United Nations. 2015. Available: https://www.undp.org/sustainable-development-goals [Accessed 25 October 2023]

Tudor C, Van der Walt ML, Margot B, *et al*. 2016. Occupational risk factors for Tuberculosis among healthcare workers in KwaZulu-Natal, South Africa. *Clin Infect Dis*, 62:3.

Underner M, Perriot J. 2012. Smoking, and tuberculosis. *Rev Pneumol Clin*, 41(12 Pt 1): 1171–1180.

van der Water N, Yassi A, Ehrlich R. 2020. Workers' compensation claims for occupational tuberculosis in South African health workers: Outcomes and workers' experiences. *South African Medical Journal*, 110(5):389–95.

Vearey J. 2014. Healthy migration: a public health and development imperative for southern Africa. *South African Medical Journal*, 104(10):663 – 664.

Wang EY, Arrazola RA, Mathema B., *et al*. 2020. The impact of smoking on tuberculosis treatment outcomes: a meta-analysis. *Int J of Tuberc and Lung Dis*, 24(2):170-175.

WHO. Global tuberculosis report. World Health Organization. 2017. Available: https://www.who.int/publications/i/item/9789241565516 [Accessed 28 June 2022].

WHO. Global status report on alcohol and health. Geneva. World Health Organization. 2018. Available: https://www.who.int/publications/i/item/9789241565639. [Accessed 28 June 2024]

WHO. Tuberculosis data: provincial TB notifications by month or quarter. Geneva. World Health Organization. 2019. Available: https://www.globalcause.co.uk/world-food-day/malnutrition-is-a-world-health-crisis-says-who-expert/. [Accessed 28 June 2024].

WHO. Global Tuberculosis Report. World Health Organization. 2021. Available: https://www.who.int/publications/digital/global-tuberculosis-report-2021. [Accessed 28 June 2024]

WHO. Global Tuberculosis Report. World Health Organization. 2023. Available: https://www.who.int/publications/i/item/978924008385. [Accessed: 01 March 2023]

Zhang H, Li X, Xin H., *et al*. 2017. Association of body mass index with the tuberculosis infection: a population-based study among 17 796 adults in rural China. *Sci rep*, 7: 41933.

APPENDICES

Appendix I (Plagiarism Declaration)

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I **Molele Thandi Celcious** (Student number: **2465337**) am a student registered for the degree of MSc: **Epidemiology and Biostatistics** in the academic year 2025

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.

Signature: ____________________ Date: 26/09/2025

1

Appendix II (Ethics Certificate)

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Innovation)

29/11/2023

Ref: W-PR-231129-01

TO WHOM IT MAY CONCERN

Waiver: This certifies that the following research does not require clearance from the Human Research Ethics Committee (Medical)

Investigator: Mr TC Molele
Student No. (if appropriate): 2465337
Staff No. (if appropriate):

Supervisor: Dr K Wilson

School: Public Health
Department:
Division: Epidemiology and Biostatistics
Medical School
University

Project title: *Factors associated with tuberculosis amongst workers in South Africa: cross-sectional analysis of the national income dynamics study, 2017-2018*

Reason: Review of information in the public domain
No human participants will be involved in the study

Professor P Ruff
Chairperson: Human Research Ethics Committee (Medical)

Research Office Secretariat:
Third Floor, Phillip Tobias Building, corner of St Andrews and York Roads, Parktown, Johannesburg 2193
Postal address: Private Bag 3, Wits 2050
Tel Nos: +27 (0)11 717 1234/1252/2656/2700
Office E-mail: HREC-Medical.ResearchOffice@wits.ac.za
Website:
https://www.wits.ac.za/research/researcher-support/research-ethics/ethics-committees/

Appendix III: List of variables and categories

Variable	Definition	Categories
Tuberculosis (TB)	Was the respondent diagnosed with TB?	1 = Yes
		0 = No
Age	Respondent's age	1=15 - 25 years
		2=26 - 30 years
		3=31 - 35 years
		4=36 - 40 years
		5= 41 - 45 years
		6= 46 - 50 years
		7= 51 - 55 years
		8= 56 - 60 years
		9= 61 -65 years
		10= 66 - 70 years
		11= 71 - 75 years
Race	Respondent's race/ Ethnicity	1= African
		2= Coloured
		3= Asian/ indian
		4= White
Sex	Respondent's gender	
		1= Male
		2=Female
Marital Status	Are you currently married, widowed, divorced, or separated?	0=Not Married
		1=Married or living with a partner
Province	In which province were you living in 2011?	1= Western Cape
		2= Eastern Cape
		3= Northern Cape
		4= Free State
		5= KwaZulu Natal

		6= North West
		7= Gauteng
		8= Mpumalanga
		9= Limpopo
Education	Highest Level of Education	0=No Schooling
		1= Primary Education
		2= Secondary Education
		3=Post Matric Education
Body Mass Index	Respondent's Body Mass Index	1=Underweight
		2=Normal Weight
		3= Overweight
		4= Obese
Smoking	Does respondent's smoke cigarettes	0=No
		1= yes
HIV/AIDS	Were you diagnosed with HIV/AIDS	0= No
		1= Yes
Diabetes Mellitus	Were you diagnosed with diabetes	0= No
		1= Yes
Household Income	Household income for primary occupation	1= Much above average income
		2= Above average income
		3= Average income
		4= Below average income
		5= Much below average income
Occupation	Occupation Groups	0= Armed Forces
		1= Managers
		2= Professionals
		3= Technicians and Associates
		4= Clerical Support
		5= Service and Sales

		6= Agriculture/Forestry/Fishery
		7= Crafts and Trade workers
		8= Plant and Machine Operators
		9= Elementary occupations
Employment Status	Which of the following best describes what you were doing one year ago?	
		1= Employed
		2= Unemployed
		3= Self-employed
		4= Casual work
		5= Subsistence farming
		6= Assist business
		7= Retired or old
		8= Student
		9= Homemaker or childcare
		10= Sick or living with disability
		11= Pregnant
Sector	Sector Employed in	0= Private households
		1= Agriculture/hunting/forestry/fish
		2= Mining/quarrying
		3= Manufacturing
		4= Electrify/gas/water supply
		5= Construction
		6= Wholesale/retail trade/repair
		7= Transport/storage/communication
		8= Financial intermediate/insurance

		9= Community/social/personal service

Appendix IV: Goodness of fit for multivariable analyses for occupation group and factors associated with TB among workers in South Africa using NIDS.

Model	AIC	BIC	R-Squared
Reduced	1531.329	1767.725	0.1517
Goodness of Fit			**P – Value**
Reduced Model			0.5528

Appendix V: Turnitin Report

Ndlovu

30 September 2025

Turnit in Report Molele TC.docx

ORIGINALITY REPORT

12%	11%	5%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

KWilson

PRIMARY SOURCES

1	pmc.ncbi.nlm.nih.gov Internet Source	1%
2	wiredspace.wits.ac.za Internet Source	1%
3	www.science.gov Internet Source	1%
4	www.ncbi.nlm.nih.gov Internet Source	1%
5	researchspace.ukzn.ac.za Internet Source	1%
6	chlaep.org.uy Internet Source	<1%
7	contraceptionmedicine.biomedcentral.com Internet Source	<1%